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THIS ISSUE

"BEST IN CLASS" Education Course – Superabrasives Materials, Principles & Applications

News & Notes

High Performance Machining of Brake Discs with PCBN Cutting Materials & customized Tooling

IDA Member Companies

Guest Editorial

Grinding of γ-Titanium Aluminide with Superabrasives

New Products

Advanced Processes for the Precision Bore Finishing of Hydraulic and Automotive Components

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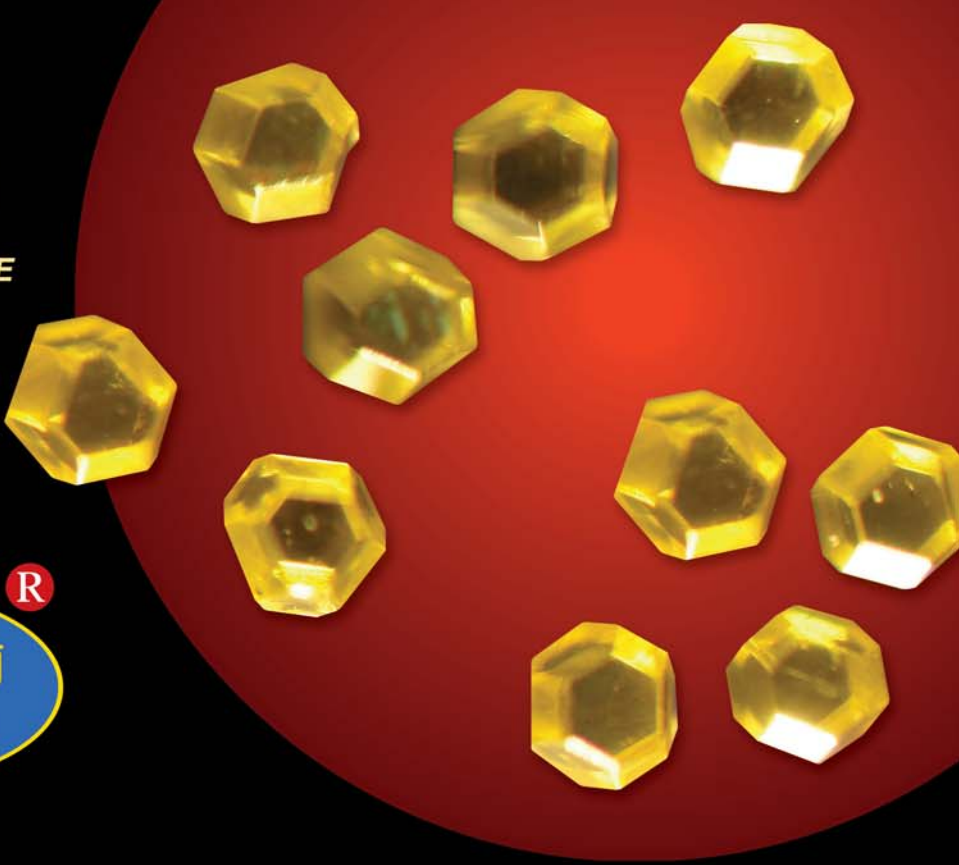

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COVER PHOTO

Cover is illustration of the difficult parts and materials used throughout industry and the crystals and polycrystallines used to bring these components into a finished state." Grinding and Machining of these difficult materials does pose a "jungle" of problems and difficulties solved by superabrasives. Photo collage courtesy of Sandvik Hyperion.

CORRECTION NOTICE:

In the summer issue of Finer Points the Board of Directors listing incorrectly had Matt Collier with Vollmer of America. Matt Collier is with Element Six US Corporation

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FINER POINTS is the longest running publication devoted exclusively to the understanding, selection and application of diamond, cubic boron nitride and related materials. It is edited for recipients who are involved in some way with these "superabrasives", either as providers of the materials, producers of products containing the materials or users of these products (e.g., grinding wheels, dressing tools, drill bits, saw blades, sawing wires, cutting tools, polishing compounds, CVD film products, etc.).

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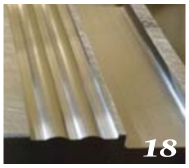
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A Finer Point of View…

PRESIDENT
Keith Reckling

We are now entering the fourth quarter of 2015 and time is passing quickly.

Mark November 17 and 18 on your calendar for the IDA Education course being held in Charlotte North Carolina. The education committee has planned an excellent program with practical demonstrations. Refer to our website www.superabrasiveseducation.com

I continue contacting members and have had some interesting conversations. The most interesting conversation was with Butch Peterman who was IDA President in 1988. He has initiated a program called Manufacturing with Heart Inc. which is aimed at small manufacturing companies in the USA to improve productivity. For more information visit www.abrasive-tech.com.

I am pleased to announce that Sean Gilmore, Engis Corporation has agreed to Chair the Trade Association Partnering committee. We have identified a number of small trade associations whose members use diamond tools and we are hoping to work with them to get ideas on ways to attract manufacturing back to the USA.

We have over the past few years established a close working relationship with the United Abrasive Manufacturing Association (UAMA) and in April 2016 will be holding our annual meeting in Longboat Key Florida in conjunction with UAMA. IDA Members please plan to attend. Note dates April 11-13 on your calendar.

I appeal to all IDA Members to please contact me if you have any ideas or suggestions for activities or programs that the IDA should be undertaking. My e-mail address is kreck25923@aol.com and phone is 914-674-8629

Sincerely,

Keith A Reckling

Keith Reckling, IDA President 2015
Industrial Diamond Association of America

There's a wonderful world around us. Full of fascinating places. Interesting people. Amazing cultures. Important challenges. But sadly, our kids are not getting the chance to learn about their world. When surveys show that half of America's youth cannot locate India or Iraq on a map, then we have to wonder what they do know about their world.

That's why we created MyWonderfulWorld.org. It's part of a free National Geographic-led campaign to give your kids the power of global knowledge. Go there today and help them succeed tomorrow. Start with our free parent and teacher action kits. And let your kids begin the adventure of a lifetime.

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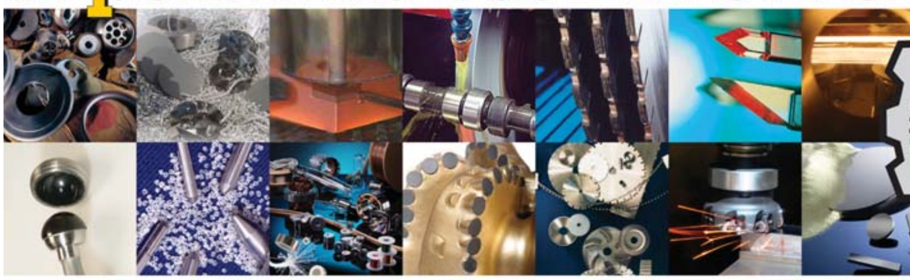

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ATTENDEES MAY SELECT ONLY THE ONE DAY OF MACHINING OR GRINDING AT $275 EARLY PAYMENT (BY OCTOBER 15, 2015) AT $250 USD

Classroom technical and instructional sessions will be highlighted by laboratory demonstrations and class interaction featuring:

- Truing & dressing applications
- Grinding demonstrations and surface analysis
- Machining of exotic materials
- Thermal Testing & evaluations
- And more!

OBJECTIVE

"Superabrasive Materials Principles and Applications" is sponsored by the IDA and designed specifically to educate on the use of industrial diamond, cubic boron nitride (cBN) materials classified as superabrasives. It is Non-commercial, unbiased and representative of accepted principles and practices. Content will include a wide range of products and applications for the automotive, aerospace, medical, electronics, optics and other industries using superabrasives. The attendee will be educated in the primary areas of grinding and machining with peripheral explanation for other uses, such as non-abrasive applications.

WHO SHOULD ATTEND?

This Course will educate End Users processing materials made from difficult to machine and grind materials such as hardened steel, stainless steel, superalloys, titanium, high silicon aluminum, composites, ceramics, bi-metals, metal matrix composites, cermets, glass, and more! It will also educate Machine Tool Builders, Abrasive suppliers, Raw Material Suppliers, Machine Operators, Wheel Makers, Tool Makers, Research Scientists, Academia, Engineers, Sales Personnel or anyone wishing to learn more about superabrasives.

INSTRUCTORS ARE INDUSTRY EXPERTS WITH MANY YEARS COMBINED EXPERIENCE!

Each one has with "real world" knowledge of superabrasives, applications and characteristics. They have already established manufacturing operations in aerospace, automotive and literally every other production operation around the world. Now, you can learn what superabrasives are, where they are used and the characteristics and properties that affect their performance in manufacturing operations. Do you want to understand wear mechanisms in machining and grinding? What is friability? What is a rake angle? What affects chip formation? What crystal is used in a given application? How does burn and thermal damage affect structural integrity of a part? What is residual stress in metal components such as turbine engine fan blades? Why true & dress a wheel? What are the different coolant types and delivery systems? What is edge prep on a cutting tool and why is it performed? What is the Modulus of Resistance and what abrasive performs best on a particular workpiece material and why? If you currently are using conventional abrasives you will learn the advantages of superabrasives and how they can be applied to increase productivity, reduce scrap and improve the cost effectiveness in manufacturing operations.

World Renowned Industry Grinding Expert Jeff Badger, "The Grinding Doc" will be a featured presenter at the Industrial Diamond Association's Superabrasives Materials Principles & Applications Course in November, 2015

About the Grinding Doc

Dr. Jeffrey Badger is an expert in the industrial process of grinding. He works independently as a consultant, helping companies around the world improve their grinding operations and troubleshooting grinding problems. He has worked in grinding facilities in over 30 countries. Dr. Badger is the author of the regular question/answer column "Ask The Grinding Doc" in Cutting Tool Engineering. He is well known for his practical, down-to-earth, yet high-tech approach to the subject.

Attila Szucs, President of Advanced Superabrasive, Inc., the Industry Leading Manufacturer of Truing & Dressing Machines will be instructing on truing and dressing and providing live demonstrations of this operation at the Industrial Diamond Association's Superabrasives Materials Principles & Applications Course.

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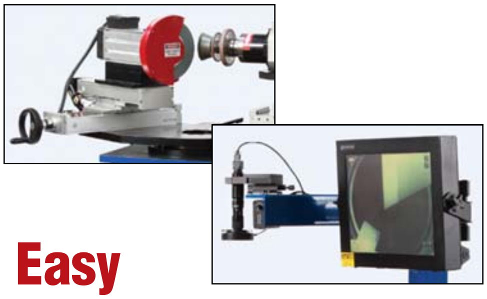

Wheel Dressing Made Easy

NEWS &notes

FIVES REINFORCES ITS OFFER TO THE AEROSPACE INDUSTRY WITH THE ACQUISITION OF THE AMERICAN COMPANY LUND ENGINEERING.

Paris, September 9, 2015 – With Lund Engineering, Fives is expanding its automation offer for composite parts manufacturing, enlarging its range of equipment, and increasing its process expertise. Fives has just finalized the acquisition of this American company, which is highly respected for its technological excellence in numerous manufacturing processes and is a preferred partner to the market leaders in the US aircraft industry. Founded in 1995 and based in Seattle (USA), Lund Engineering is an engineering firm known for designing and building electro-mechanical equipment for the manufacture of composite aerospace structures and components. Visit: www.fivesgroup.com

ENGIS® AND DELAPENA ENTER AGREEMENT TO EXPAND GLOBAL PRECISION BORE HONING OFFERING

Sitting: Stephen Griffin, President, Engis Corporation
Top Left: Martin Elliott, President, Delapena Group
Top Right: David Arthur, Chairman, Delapena Group

Engis Corporation of Wheeling, IL USA and Delapena Group of Cheltenham, Gloucestershire, UK announced today that an agreement has been signed for the distribution of the Delapena stroke honing machine tools in North America and East Asia by the Engis Group. “The Engis – Delapena agreement creates a complete global offering of honing/bore finishing systems, backed by technical experience and a long history of service to the honing industry,” said Stephen Griffin, president of the Engis Group of Companies. Engis Corporation is a global leader in the design and manufacture of superabrasive finishing systems. The single-pass bore finishing approach, pioneered by Engis, has improved the geometry and bores of precision components throughout the industrialized world in the automotive, hydraulics, firearms and compressor markets. Engis bore finishing systems have been successfully installed for customers in the Americas, South and East Asia, as well as within Europe. The Delapena range of stroke honing systems successfully expands the capability of Engis to engineer a solution for every application, even those with smaller batch sizes. Delapena offers not only state-of-the-art machine tools, but also fixtures, abrasives and other consumables. For more information visit: www.engis.com

WEST OHIO TOOL, LOCATED IN RUSSELLS POINT, OHIO ANNOUNCED THE APPOINTMENT OF SCOTT RIES AS VICE PRESIDENT OF OPERATIONS

Beginning September 1, 2015 – West Ohio Tool is a premier producer of both carbide and PCD round tools primarily for the automotive market. The company has been in business since 1989 and producing PCD tools since 2003. Mr. Ries will be responsible for overseeing all aspects of the operation and facilitating the continued growth of the organization. He brings a wealth of knowledge and experience related to the PCD industry. Prior to joining West Ohio Tool, Mr. Ries was responsible for supporting and growing the North American PCD market for Vollmer of America for eight years. During this period of time he made numerous speeches at various conferences and seminars and published many articles in trade magazines sharing tips and insights into the use and applications of these superabrasive materials. In addition, Mr. Ries is involved with the Industrial Diamond Association as a Board Member and with the United States Cutting Tool Institute. His involvement in these organizations will continue and he is currently a member of the Education Committees of both organizations. Before joining Vollmer, Mr. Ries worked for almost 30 years at GE Superabrasives and Diamond Innovations which is now part of Sandvik Hyperion where he held many technical and managerial roles related to the manufacturing and engineering of PCD/PCBN materials. In his last role, he was responsible for all global production and engineering of these materials with 41 direct reports, conducting 7 kaizen events which resulted in tremendous increases in throughput and machine up time. He has multiple patents related to PCD materials and applications and received his Green Belt certification while leading a project that result in over $1.5 million in savings at a customer facility.

High Performance Machining of Brake Discs with PCBN Cutting Materials & customized Tooling

JOHANNES SCHNEIDER
CeramTec GmbH, SPK Cutting Tool Division

ABSTRACT

As a product of high volume production the economics and productive manufacturing of the brake discs is a fundamental issue to ensure the competitiveness of the manufacturers. The output and final cost per part are highly influenced by the manufacturing technology, the cutting materials and tooling systems applied. Further development of Ceramics and PCBN (Polycristalline Cubic Boron Nitride) cutting materials, customized tooling and work path planning are the basics for best machining results and minimum manufacturing costs.

Brake discs and brake drums of motor vehicles are made from grey cast iron in more than 90% of all applications. Cost per part and the output per time are highly influenced by the cutting materials, customized tooling and work path planning. Cutting speeds up to vc = 1200 m/min and higher and feed rates up to f = 0,8 mm are applied with high performance cutting materials in roughing. High surface qualities in the finishing process are realized by applying special geometrical designs to the finishing inserts. In combination with customized, multi inserted bladed tools, the shortest machining times and the highest productivity at optimal manufacturing cost per part will be achieved.

CUTTING MATERIALS FOR BRAKE DISC MANUFACTURING

Higher efficiency in manufacturing is mainly achieved by higher production rates and higher cutting data. Due to their unique characteristics of high hardness, wear resistance and hot hardness combined with a good compressive strength, thermal shock behavior and toughness, Ceramics and PCBN materials are perfectly suited for cutting applications at elevated cutting data, also under unfavorable conditions such as interrupted cut or uneven depths of cut.

During the last decades, silicon-nitrides / SiAlON and PCBN grades became the standard cutting material for all HPC-turning of grey cast iron materials. Especially when machining high volume components, such as brake discs, the highest speeds and feeds are achieved, leading to shorter machining times, increased productivity and unbeatable economics. PCBN Cutting materials play an important role in High Performance Machining of cast iron materials (GJL).The process efficiency in cutting CI can be related directly to the machining parameter.

PCBN as a non-metallic material and inorganic compound is fulfilling the definition of a ceramic material with special characteristics. PCBN cutting materials are characterized by a multi-phase structure comprising of PCBN grains of different sizes embedded in a binder matrix (either of metallic or ceramic origin). Depending on the grain size, the percentage share of PCBN, the binder material used and the manufacturing process, cutting materials with different characteristics and areas of application can be realized.

With increasing volume content of PCBN, the resistance of the material to abrasive wear will increase. As abrasive wear is dominating when machining grey iron, PCBN grades with a high PCBN content (75-95% PCBN) are used for machining grey iron materials. Typically they are containing a ceramic binding phase and medium to small grain sizes (see figure 1). PCBNs for cast iron machining are characterized by a high thermal stability combined with an excellent toughness. They possess a high wear resistance and exceptionally high cutting edge stability.

Conventional ceramics, e.g. SiAlON materials are characterized by a specific ratio of the alpha- and beta- modifications of the SiAlON grains with that the wear resistance and toughness behavior of the alpha- and beta- SiALON grades can be defined. A further increase of the hardness of the a/b - SiALON can be achieved by adding additional hard particles to the material. Additionally, new manufacturing methods enable the realization of extremely hard

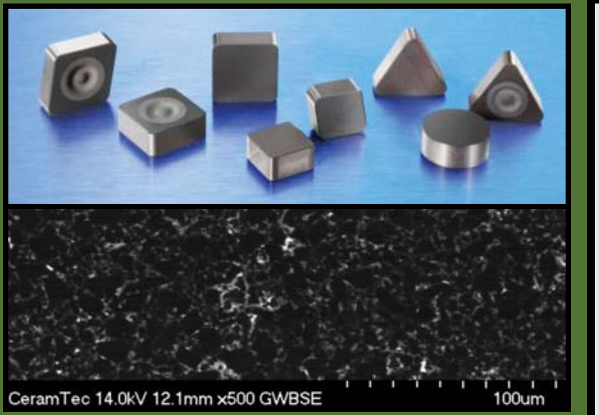

Figure 1: PCBN Inserts for grey cast iron machining and typical grain structure.

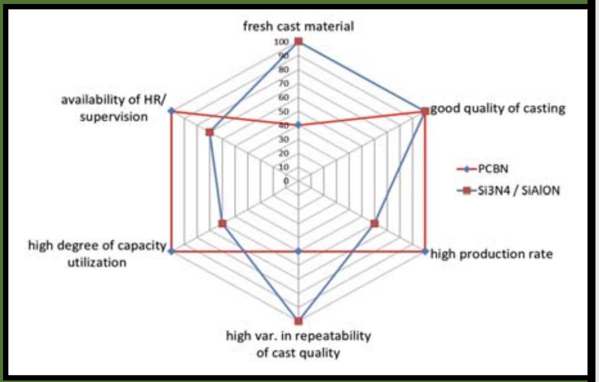

Figure 2: Material and machining characteristics are defining the selection of the cutting material PCBN or SiAlON for machining brake discs.

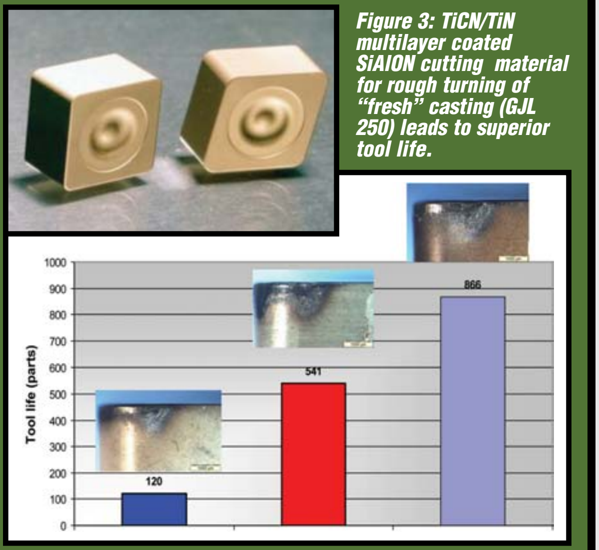

Figure 3: TiCN/TiN multilayer coated SiAlON cutting material for rough turning of "fresh" casting (GJL 250) leads to superior tool life.

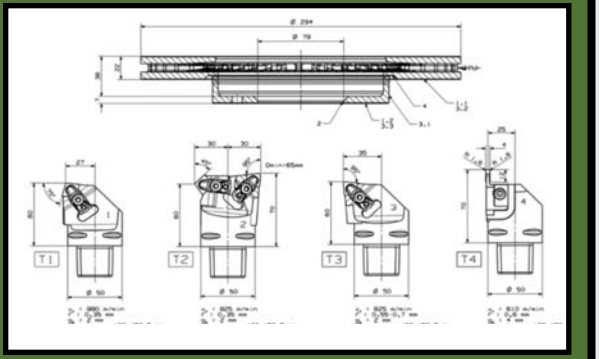

Figure 4: Set-up OP10

and wear resistant surfaces while maintaining a base upon on a tougher core of the material. Depending on the purpose of the application, special characteristics of cutting material can be adjusted to suit the application.

The selection of either cutting material, Silicon-Nitride, SiAlON, Coatings or PCBN, depends on various influences. The following are the main topics concerning the workpiece material and the lay-out of the machining process which should be taken into account:

- Grade of work piece material, its hardness and age.
- Casting quality and constancy.
- The production rate per day.
- The degree of utilisation of the given machining capacity.
- Management of the actual available staff for supervising the manufacturing process.

This is illustrated in figure 2.

As far as the cutting process and the required tolerances of the workpiece are concerned, the following issues should be considered:

- Required Surface quality.
- Dimensional and geometrical accuracies.
- Process reliability and flexibility.
- Length of cut.
- Variation in depth of cut and interrupted cutting.
- Required feeds and speeds.

All these influences have to be evaluated. According to the result, PCBN or Silicon Nitride / SiAlON or coated cutting material will be recommended as a preferred first choice for the given application.

In the high performance turning of brake discs Ceramics and PCBN enable cutting speeds up to vc = 1200 /min and higher, as well as feed rates up to f = 0.8 mm in roughing operations. Therefore the cycle time for turning can be reduced drastically, while maintaining the close dimensional and accuracy tolerances (flatness; parallelism; lateral run out, thickness variation) required of the work.

MACHINING OF "FRESH" CASTINGS

The machining of "fresh" cast iron material poses a special challenge in terms of achievable tool life. Parts are considered as "fresh" castings, when machining of the parts will take place within 2-4 days, or even earlier, after the casting process has taken place.

In this case the tool life drops drastically compared with the machining of "aged" cast iron. PCBN cutting materials are not recommended for such applications due to a poor cost / performance ratio. In this case coated SiAlON grades should be applied.

When roughing the brake path of a "fresh" cast rotor (material GJL 250) at vc = 1100 m/min, doc up to 3.0 mm and a feed rate f = 0.80 mm the best result in tool life is achieved with a multi-layer coated SiAlON insert (see figure 3).

LAY OUT OF TOOLING FOR RELIABLE BRAKE DISC MANUFACTURING

A typical machining lay-out for brake discs contains normally three (OP10 to OP 30) or sometimes also four set-ups of the part (OP10 to OP40). The number of set-ups is independent from the choice of the used cutting material. Also the range of speed and feeds applied is mostly identical for PCBN and SiAlON cutting materials. As explained above, either of them can be chosen according to the actual situation on the shop floor, the demands in terms of cost efficiency and machining requirements.

A typical brake disc machining set-up for OP10 to OP 40 is shown in figures 4-7. Overall a number of only 12 tools are involved (except for drilling) in the complete machining process.

The finishing of the mounting face and the pilot bore are always done in the same operation. Typical cutting parameters are in the range of cutting speed vc = 800 – 1200 m/minh, feeds f = 0.40 – 0.50 mm and doc = 2.0 – 4.0 mm for roughing sections. For finishing the following typical data are applied: vc = 600 -1200 m/min; f = 0,25 – 0,50 mm and doc = 0,4 – 0,6 mm.

The typical machining time per set-up is around 35 sec to 40 sec., including the idle time. As a matter of fact, the portion of idle time in each set-up is up to three times the real cutting time. Speeding up the process requires therefore not only the application of high-speed cutting materials and corresponding cutting data but also the use of intelligent tooling lay out.

To fulfill this, specially designed multi insert tools are designed and implemented to shorten the idle time by minimizing the number of tool changes and of indexing of the turret, see figure 8 and 9.

Figure 9 illustrates the lay- out of a multi inserted bladed tooling according to the machining task in the specific set-up. In this case the tool holds three inserts of PCBN. Insert no. 1 is machining the pilot bore and the chamfering on the internal diameters of the hat. Insert no. 2 is turning the brake path, whereas insert no. 3 is doing the chamfers on the outer diameter and OD turning of the disc.

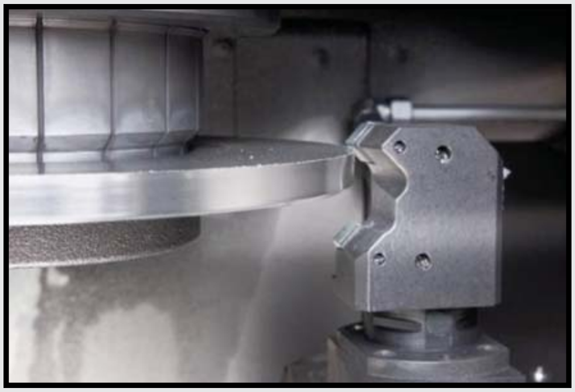

Figure 8: Multi insert tooling saves idle time and increases productivity (photos courtesy of Weisser)

This customized tool saves two additional tool holders and – even more important- it saves two times of indexing of the turret to get the next insert in contact with the workpiece. This is equal to a time of approx. 2 x 6 sec = 12 sec. by which the cycle time in this specific set-up of the brake disc machining can be shortened. Taking into account that the cycle time is generally in the range of 35 to 60 sec. the economic advantage of such a tool design becomes significant.

For the final stage machining of the brake faces so called straddle tools are applied (see figure 10). NC drives and double guide ways for the straddle tools guarantee a maximum cutting performance and highest surface quality of the part. For the cutting insert (based on either PCBN or Ceramics) ZZ-geometries (ZZ = special insert radius design, also called “Wiper”) are implemented.

These “Wiper” geometries allow for higher feeds, higher output and reduced manufacturing costs. In the specific case of the finishing of

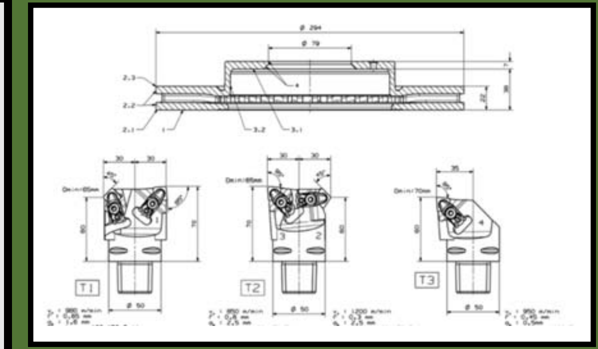

Figure 5: Set-up OP20

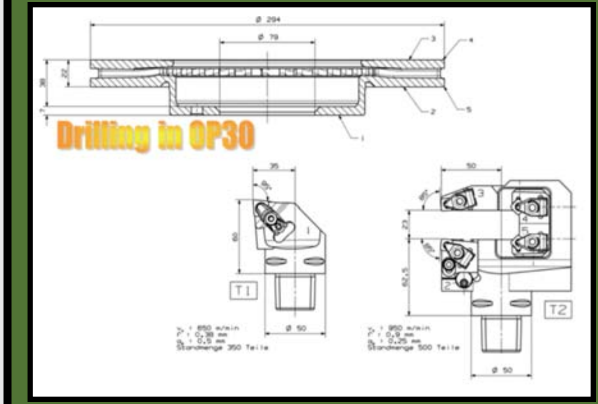

Figure 6: Set-up OP30

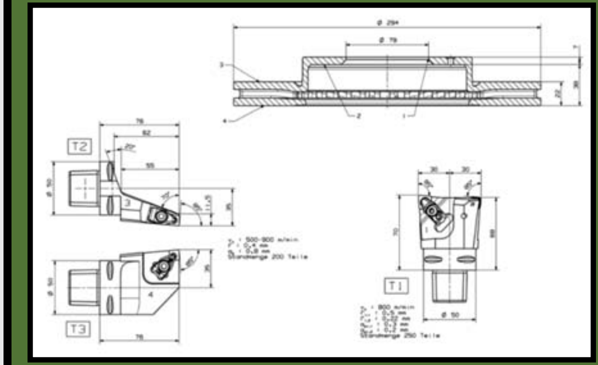

Figure 7: Set-up OP40

Figure 4-7: Example for a tool path planning for a complete rotor machining in OP10 to OP40.

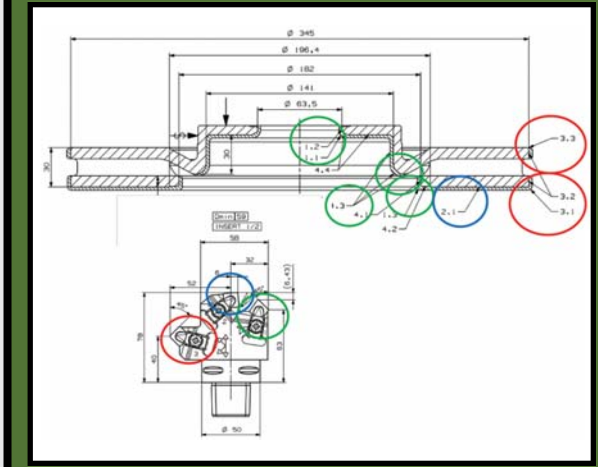

Figure 9: Customized tooling saves manufacturing costs.

the brake drum, figure 11 is machined with a PCBN grade at vc = 1400 m/min, doc = 0.10 -0.40 mm with a ZZ-geometry SNGN090412 85Z075 and a feed rate f = 0.40 mm replacing a conventional insert geometry SNGN090412 which was running at f = 0.18 mm to achieve the same requirements in terms of surface quality and dimensional accuracy.

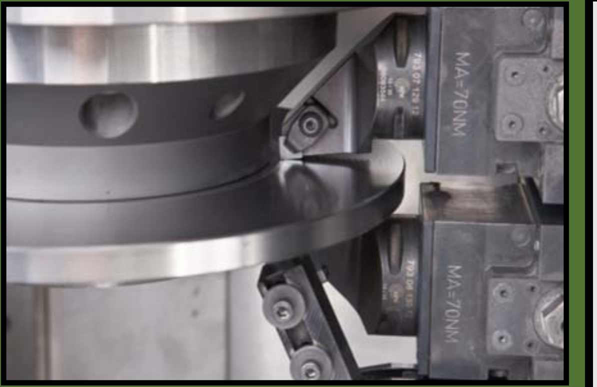

Figure 10: Straddle tool with damping advice for final stage finishing of brake path with PCBN and ZZ-geometry (Wiper) (photo courtesy of Weisser)

Figure 11: High feed and short machining time in finishing is achieved with special geometrical design of the PCBN cutting insert.

Due to the applied cutting data, the machining time was reduced from 8.8 sec. to 3.6 sec. only. In addition, the tool life increased from 1000 parts / edge to over 2400 parts/edge. This led to an enormous gain in productivity and cost effectiveness as shown in figure 12.

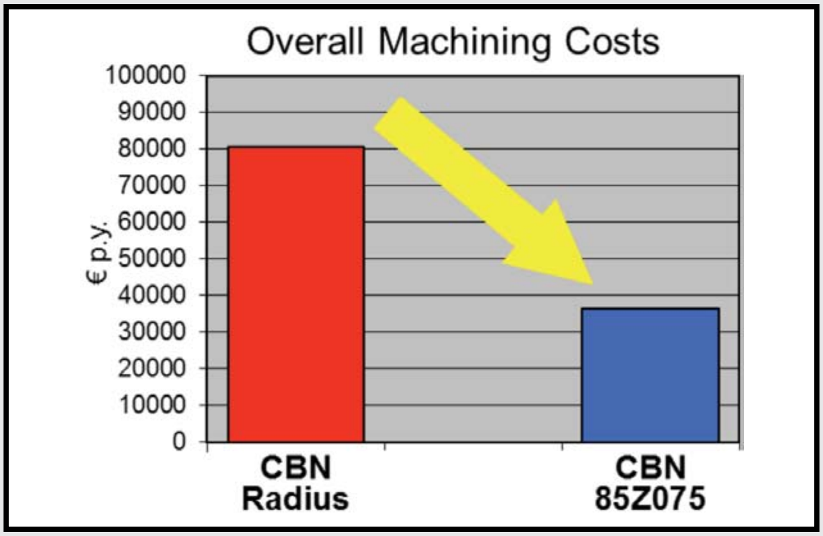

Figure 12: Finishing the brake path of a brake drum with ZZ-geometry and PCBN grade at high speed results in enormous cost savings.

TYPICAL MACHINE TOOL CHARACTERISTICS FOR BRAKE DISC MANUFACTURING

Modern machine tool designs for rotor machining are mainly designed as vertical pick-up machines. They are distinguished by a high thermal stability, high rigidity and best damping behavior. Beside rough and finish turning, the drilling of the rotors is also integrated in the machine tool. Regularly the drilling is integrated in OP30 or OP40.

The machine tool is either equipped with one single spindle or two spindles per machine. Figure 13 shows a lay out for double spindle machine tool. In this case the machining of OP10 and OP20 is performed on one single machine tool lathe.

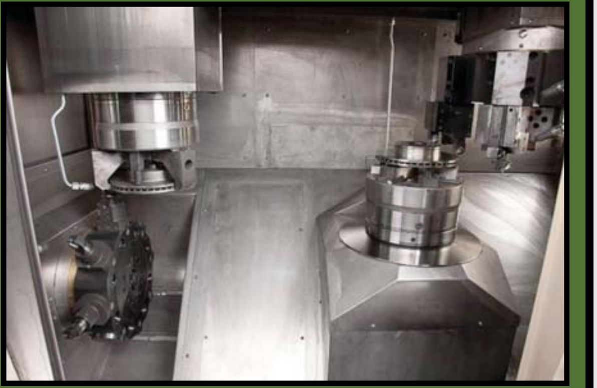

Figure 13: OP10 and OP20 – combined in a double spindle machine tool (photo courtesy of Weisser)

Modern machine tools are designed to fit all chip removal machining requirements for rough turning, drilling and finish turning. A typical lay-out for the entire machine tool line depends on the number of set-ups and the chosen type of machine tool (single or double spindle). A complete line may typically consist of three to four single spindle machines or even two double spindle machines only. ●

SUMMARY OF ARTICLE

The application of ceramics - PCBN and SiAlON - on state of the art machine tools (vertical pick-up lathes with single or double spindle), at adequate cutting data and combined with an optimized planning of the entire process chain can lead to cycle times of less than one minute per part. To shorten the idle time and to decrease manufacturing costs further, tailored multi insert tooling is used. This guarantees a high reliability in the production, best cost effectiveness and lowest manufacturing costs per part.

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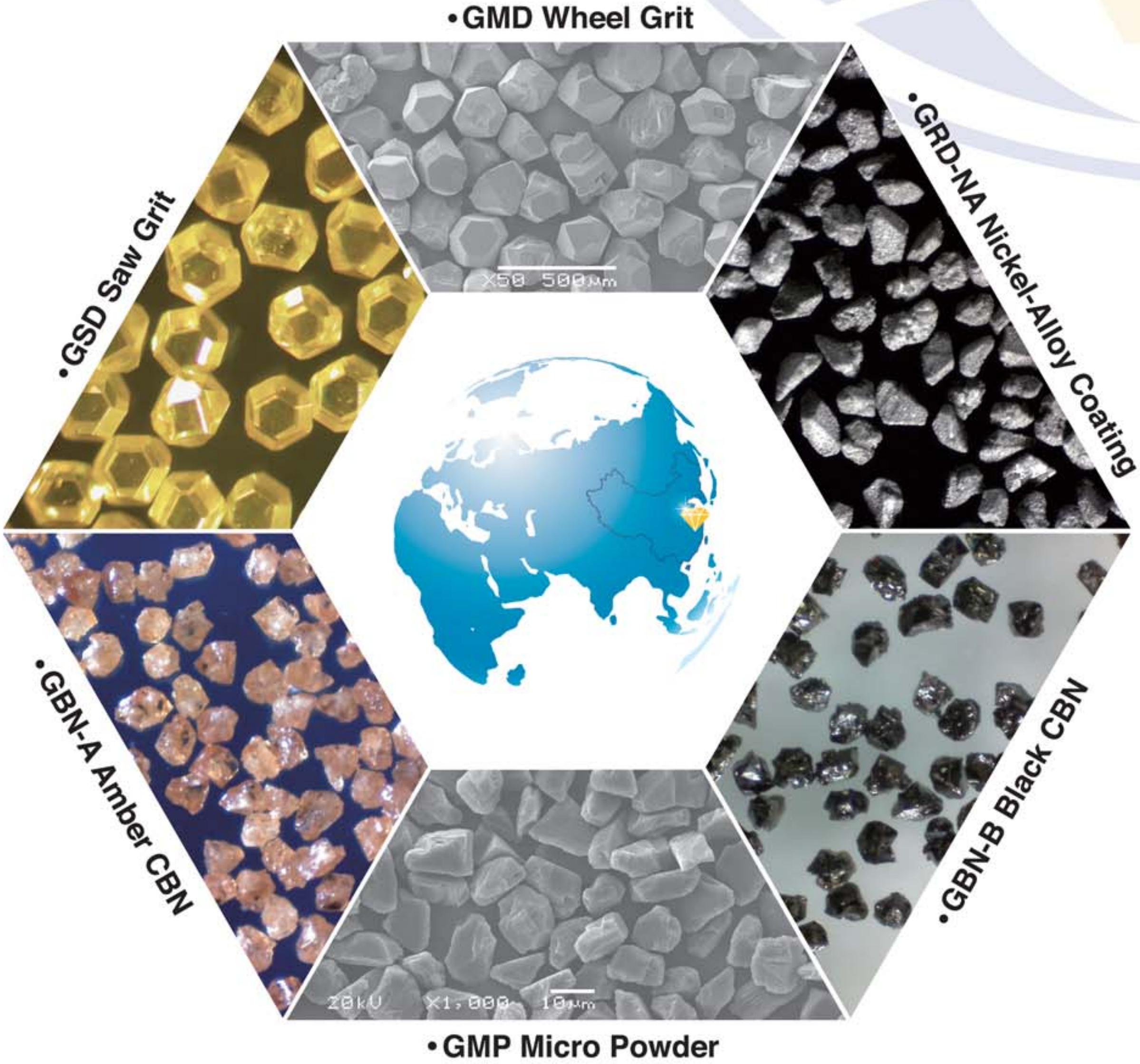

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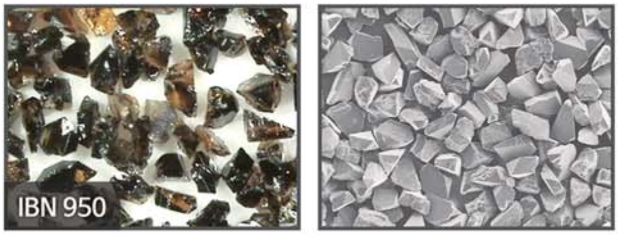

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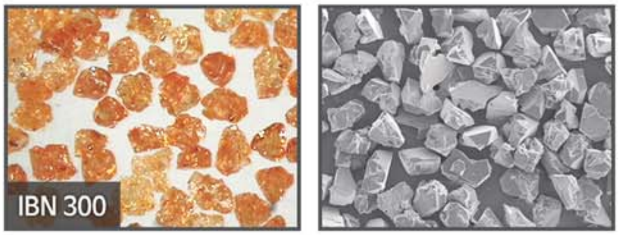

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MARCEL DAANE

GUEST EDITORIAL

NINE BRAIN-AGING “SINS” THAT KILL YOUR COMPETITIVE EDGE

By Marcel Daane

It’s Monday morning, and Michael, a senior executive at a global telecommunications company, faces the week utterly exhausted. Only 38, he’s been a high-level leader with the firm for more than a decade. Once, he was a wunderkind, an “energizer” on the fast track to become the company’s youngest-ever CEO. But now, Michael is perpetually depleted as he struggles with stress and anxiety every day. This state of mind (and body) is not just killing his performance capacity; it’s also killing his brain cells and forcing a state of chronic fatigue, decreased resilience, reduced motivation and mental focus, and ultimately, accelerated aging. Michael is not alone. As performance demands grow and resources shrink, we all struggle to do more with less. Without proper coping skills, we can all slide down a slippery slope of chronic exhaustion into debilitating burnout. The good news is we can affect how fast our brain ages, depending on how we treat it throughout life. Research at King’s College in the UK shows the brains of elderly people who practice a healthy lifestyle are the same as people decades younger. Are you committing predictable brain-aging “sins” on a regular basis? Here are nine of the most damaging:

BRAIN-AGING SIN #1: You regularly forgo a daily walk in favor of a flop on the couch. After a long day, it’s tempting to talk yourself out of exercise. But sedentary behavior doesn’t reward your fatigued brain and body—it makes you more fatigued. Movement produces proteins and hormones in the brain that stimulate memory and make you more alert. One such protein is called brain-derived neurotrophic factor (BDNF), which is produced only during exercise and works like fertilizer to help new brain cells grow. Thus, a daily walk in the office, around the parking lot, or through the airport helps keep your energy level up and your brain young.

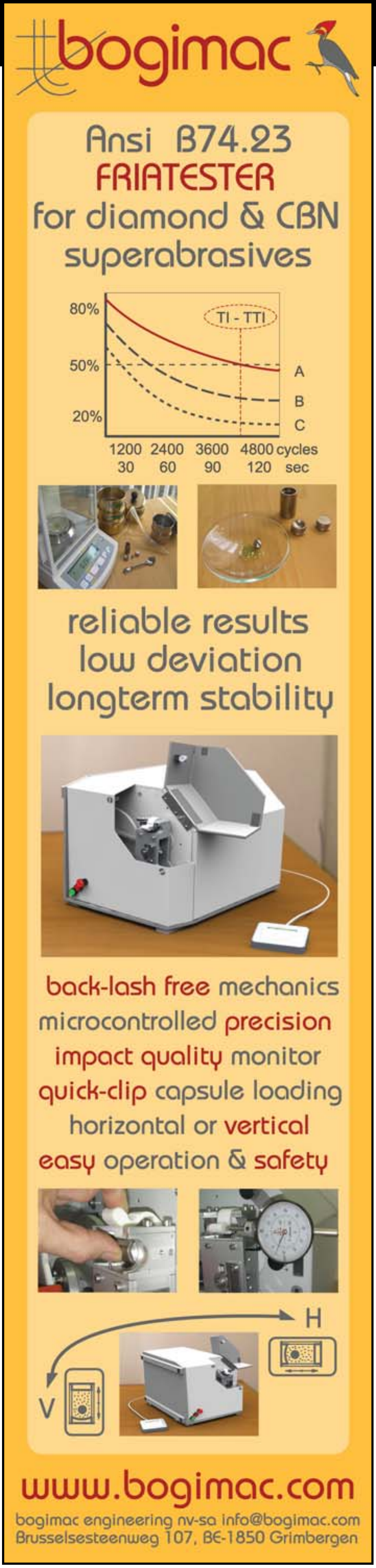
BRAIN-AGING SIN #2: You hit the snooze button (again) and run out of time for breakfast. Robbing your brain of essential nutrients in the morning is a big mistake. Just like an athlete needs fuel for the body to perform and recover from training, an executive needs fuel for the brain to perform and recover from stress. In fact, just as an athlete’s muscles shrink without proper refueling, so too do the executive’s “mental muscles.” Brain cells die with repeated exposure to stress, resulting in a loss of brain mass, function, and ability. To fuel and protect your brain, start your day with breakfast. Choose brain healthy foods, such as oatmeal topped with berries, cinnamon, and walnuts.

BRAIN-AGING SIN #3: You skip lunch to take an emergency conference call. If your workday includes last-minute meetings, emergency conference calls, or other urgent craziness, taking time to refuel your brain can seem impossible. But without fuel, your brain can’t perform. The brain has a minimal capacity to store its own fuel, glucose, so it relies on you to feed it regularly. When you skip meals, the regions of your brain responsible for self-regulation, empathy, and solution-based thinking begin to shut down. You become hyper-responsive to stress, brain cells in your memory processing centers die, and your brain ages more rapidly. Bring your own healthy lunch or snacks to work, so you have food available no matter how crammed your day becomes.

BRAIN-AGING SIN #4: You don’t stock up on good snacks (so you naturally grab bad ones when temptation strikes). Stress and fatigue are notorious triggers for bad-food binges. That’s why many people grab chips or cookies and mindlessly devour them while multitasking. The problem is that stress causes chronic brain inflammation, and processed foods like cookies, sodas, and cakes only add fuel to the inflammation fire. This speeds up brain cell destruction, resulting in memory decline similar to what we see in Alzheimer’s patients. If your workplace (or your home) is stocked with cookies, sodas, candies, and chips, of course you’ll reach for them when stress hits. The remedy is to plan ahead. Bring your own healthy snacks—those that build memory capacity, improve physiological brain balance, help you perform complex mental tasks, reduce symptoms of stress and anxiety, and keep you focused—and eat them instead. Such snacks might be as simple as an apple, banana, or a handful of almonds.

BRAIN-AGING SIN #5: You swill coffee and soda instead of water. You may think your morning jolt of caffeine is revving you up, but it really isn’t. Yes, it creates a momentary lift as it blocks neurons in the brain that make you feel tired, but the lift quickly declines and fatigue sets in. The more you consume, the greater the impact of stress on your brain, and the more dehydrated you become. The best hydration is water, which transports nutrients and oxygen into your tissues and brain cells. Without enough water, our bodies and brains can’t function properly. Imagine your blood slowly turning to mud, making it difficult for nutrients to travel throughout your body. Imagine your brain cells turning from juicy grapes to dried-out raisins. Dehydration leads to serotonin deficiency, which means less stress-resilience, more depression, poor sleep, and memory loss. To keep your body and brain hydrated, drink a half-ounce to one ounce of water per pound of bodyweight per day. So someone who weighs 150 pounds needs between 75 to 150 ounces of water per day.

BRAIN-AGING SIN #6: You regularly “relax” with an after-work beer or a nightcap. No one is saying you have to be a teetotaler. The occasional drink with friends is okay. But don’t go beyond one 250-ml glass of wine or two 8-oz glasses of beer a day – at most. Alcohol is not so



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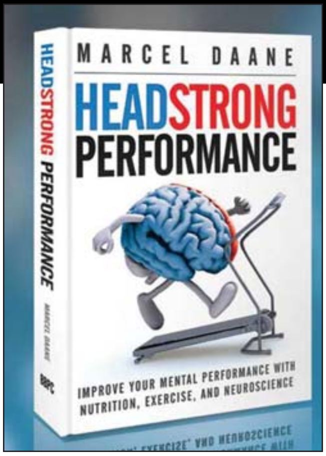
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much a relaxant as it is an anesthetic combined with a stimulant. During a stressful day, your brain cells are stretched beyond capacity. As we drink alcohol, our brains are anesthetized and overstimulated, which causes additional trauma to the brain and compounds the damage. There are more effective ways to recover from stress. You can practice mindfulness meditation, go for a walk or a run, or take a yoga class. All of them reestablish calm in the brain and body, and help you build brain cells rather than kill them.

BRAIN-AGING SIN #7: You sacrifice sleep on the altar of work. Many executives today still think it's a badge of commitment to regularly sacrifice sleep in favor of work. But studies have shown that a single 90-minute reduction in sleep decreases performance and alertness by a whopping 32 percent. Furthermore, a chronic lack of sleep causes significant decreases in brain volume and memory while making us gain body-fat, raising our blood pressure, and causing heart disease and diabetes. We all need different amounts of sleep at different stages of our lives, but the magic number still seems to be around the eight-hour mark. If you find yourself needing to pull an all-nighter, try taking periodic naps during the day. A 30-minute nap can greatly increase alertness, focus, and memory.

BRAIN-AGING SIN #8: You skip water cooler chats. In today's always-on technology-fueled culture, it can be tempting to lock yourself in your office or hide away in your cubicle, chasing the rabbits of deadlines all day. No wonder research suggests that more than 50 percent of employees suffer from feelings of isolation at work. Humans need interaction and connectivity, just as we need food and water. One study showed that social isolation results in reduced capacity for planning, communicating, impulse control, imagination, and empathy. Conversely, social interactions help us learn and see other perspectives. They help us relax and feel happier. They make us more effective when we do return to focusing on work. Structure your day to allow social time even if your brain tells you it has too much work to do.

BRAIN-AGING SIN #9: You sit and sit (and sit some more). Scores of research show that sitting more than six to eight hours a day increases brain stress and early mortality, not to mention exhaustion, stiff necks, heavy limbs, and aching backs. If all that isn't disturbing enough, consider that too much sitting actually thickens your connective tissue over time until you lose your range of motion (not unlike the "Tin Man" in The Wizard of Oz). The human brain was designed to function best in an environment that required physical movement such as foraging and hunting for food. Many of the brain regions involved in our current daily functions are directly linked to the brain neurons involved in movement. While sitting for hours, the neurons switch off, and your brain's capacity drops below that of a person who is decades older than you. That's why you must stand up and move around during the day. Stand at your desk; conduct stand-up or walking meetings; take regular walks away from your desk; walk or stand while thinking. The lesson is clear: Overworked executives can go a long way toward keeping their brains young and highperforming. We may not be able to control our workload but we can control our lifestyle choices.

ABOUT THE AUTHOR: Marcel Daane is the author of Headstrong Performance: Improve Your Mental Performance with Nutrition, Exercise, and Neuroscience. As the CEO of Headstrong Performance, a Singapore-based, globally operating boutique consulting firm, Daane helps organizations, leadership teams, and executives transcend their current performance plateaus, manage stress, improve focus, ignite creativity, and drive change. To learn more, visit www.marceldaane.com

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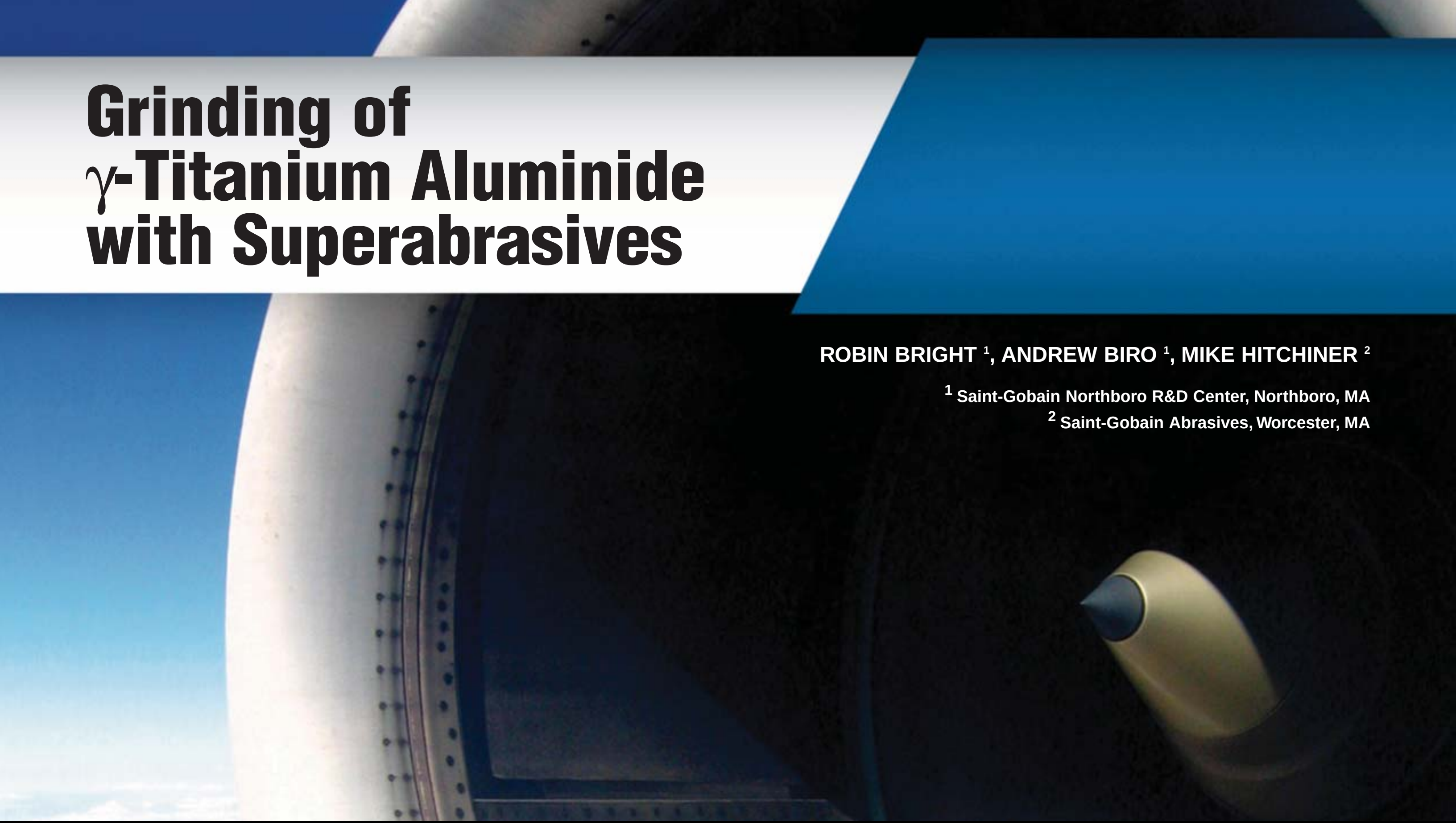

Grinding of γ-Titanium Aluminide with Superabrasives

ROBIN BRIGHT [1], ANDREW BIRO [1], MIKE HITCHINER [2]

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ABSTRACT

As gamma titanium aluminide (g-TiAl) becomes increasingly attractive for use in high-temperature engine components, the ability to effectively and economically manufacture such components has become a key challenge for engine OEMs and their suppliers. Machining and grinding operations are particularly problematic, due to the brittle and burn-sensitive nature of this material. The traditional approach for grinding g-TiAl includes the use of vitrified-bonded silicon carbide (SiC) wheels with high dress frequencies to avoid material damage (cracking, oxidation burn). This paper details results from recent g-TiAl grinding experiments utilizing superabrasive wheels, and compares results to those obtained from testing of traditional SiC grinding wheels. Results show a substantial technical benefit of diamond abrasive relative to both SiC and cubic boron nitride (cBN), and also demonstrate the potential of new dressable metal-bond wheel technology for high-productivity damage-free grinding of this material.

1. Introduction

The need for improved fuel efficiency of commercial and military aircraft engines continues to drive the development and implementation of advanced materials, specifically where high-temperature stability and increased strength-to-weight ratios are critical. Recently-developed and next-generation engine designs will rely heavily on such advanced materials, which include the γ-TiAl family of alloys. This material has already been implemented in low-pressure turbine blades for select engine types, and plans to utilize γ-TiAl for additional engine components have also been announced. γ-TiAl is an intermetallic compound of titanium (Ti) and aluminum (Al), and typically includes small amounts of alloying elements such as niobium (Nb), chromium (Cr), manganese (Mn), or tungsten (W). The elemental composition of the most commonly used γ-TiAl alloys falls in the region of the phase diagram between 40 and 48 atomic percent Al, as shown in Figure 1. In this region, the microstructure is termed duplex due to the presence of both g-phase and colonies of lamellar structures which contain alternating plates of g and α_2 phases. The high specific strength and temperature stability of γ-TiAl relative to conventional titanium alloys and certain nickel-based superalloys (Figure 2) make it especially attractive for aerospace applications, although its use in automotive turbochargers and exhaust valves has also been extensively investigated.

Despite the advantageous properties of this material, challenges related to the cost-effective production of γ-TiAl components have limited its widespread implementation. Specifically, the low room temperature ductility and poor thermal conductivity of this material reduce its ability to be machined by traditional techniques. Turning and drilling of γ-TiAl have been reported to result in extensive micro-cracking as well as poor tool life relative to machining of conventional Ti-alloys. Grinding has been shown to be an effective finishing method for γ-TiAl and shows tool life benefits relative to grinding of conventional Ti- alloys. However, adequate selection of abrasive products and process parameters are required to avoid part damage. As a result, grinding of this material has been the subject of several in-depth studies. Hood et al investigated the effect of grinding wheel structure, feed-rate, and depth of cut on part quality and wheel wear. They concluded that at low depth of cut, damage-free surfaces could be generated using SiC wheels, with G-ratio values (ratio of workpiece volume removed to volumetric wheel wear) up to 35, depending on the grinding conditions.

Additionally, Hood et al conducted creepfeed grinding tests with superabrasive wheels and quantified wheel speed limits and the effect of coolant type on the surface roughness of ground parts. Stone and Kurfess performed grinding tests with wheels containing diamond, cBN, and aluminum oxide abrasive grains and found diamond abrasive to result in the lowest part temperature by using embedded thermocouples in the workpiece. Additionally, Nelson et al evaluated the performance of resin-bonded diamond and conventional SiC wheels, and observed micro-cracking when using SiC wheels, which increased in severity with depth of cut. Klocke and Zeppenfield applied a thermal model to demonstrate the benefits of high table speeds for reducing heat input to a part. As an abrasive supplier, the present study was performed in order to assess current Norton/Saint-Gobain product technologies and to enable technical recommendations to our partners and end-users regarding grinding of this material.

2. Experimental

Various 200 mm (OD) x 12 mm (width) grinding wheels listed in Table 1 were subjected to non-reciprocating surface (slot) grinding according to experimental conditions detailed in Table 2. The composition of the workpiece was (in atomic %) 48% Ti, 48% Al, 2% Nb, 2% Cr (commonly designated 48-2-2 alloy) and contained a duplex microstructure. Prior to grinding, electroplated (EP) wheels were mounted on the grinding spindle to within 6 um (total indicator reading). Dressable metal bond wheels were trued and dressed according to conditions detailed in Table 2.

For each wheel type, slots of 51 mm (length) x 12 mm (width) were generated by performing individual grind passes (without dressing in between passes) until damage was observed in the components or a total stock removal of approximately 1800 mm^3 was achieved. A new slot was generated for each wheel and set of operating conditions, such that the slots would be preserved for subsequent characterization. A schematic of the workpiece can be seen in Figure 3, while the machine setup is shown in Figure 4. In addition to cumulative stock removal before workpiece damage, spindle power and resulting surface roughness (Ra) measurements were recorded for each grind.

3. Results & Discussion

3.1 Conventional SiC

Figure 5 shows the progression of specific grinding energy (SGE), defined as power consumed during the grinding process normalized to the volumetric material removal rate, as a function of cumulative volumetric stock removed from testing of the conventional SiC grinding wheel. SGE is an indicator of the efficiency of a

***Table 1:* ABRASIVE PRODUCTS TESTED**

WHEEL TYPE	**Abrasive Grit Size (avg. diameter)**
Vitrified-Bonded SiC (hardness L)	*60 grit (250 um)*
Electroplated (EP) cBN	*60/80 (250 um)*
Dressable Metal-Bonded cBN	*100/120 (151 um)*
Electroplated Diamond	*60/80 & 100/120 (250 & 151 um)*
Dressable Metal-Bonded Diamond	*100/120 (151 um)*

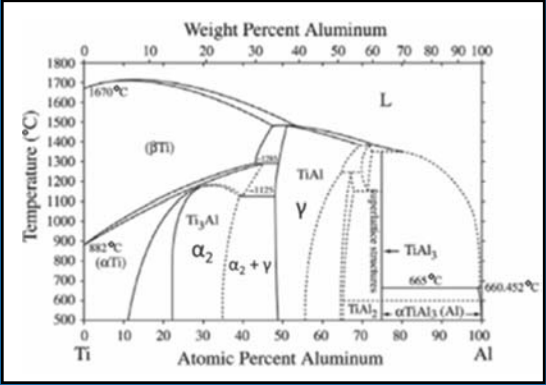


***Figure 1:* Phase diagram for Ti and Al, indicating phases in Ti alloys.**

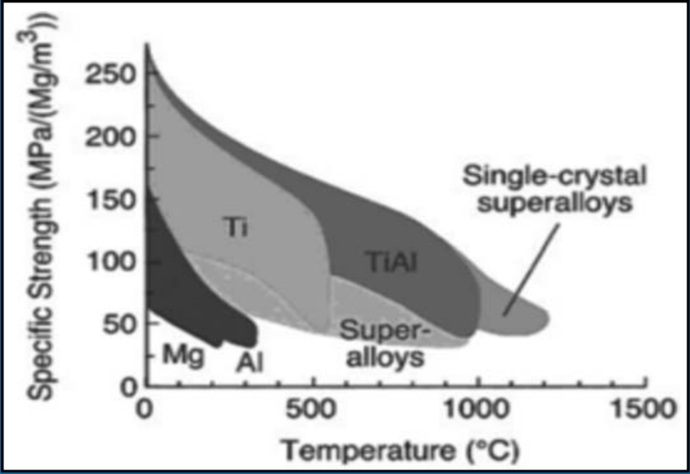


***Figure 2:* Specific strength versus operating temperature for various turbine engine-component materials.**

***Table 2:* SUMMARY OF EXPERIMENTAL CONDITIONS**

MACHINE TOOL	
Machine	In-house creepfeed grinder (7.5 kW spindle)
Grinding Mode	Slot grinding, non-continuous dress
Coolant	Trim E-812 (5%) water soluble 15.2 mm x 1.27 mm rectangular nozzle 45 liter per minute flow rate @ 0.413 MPa pressure
DRESSING CONDITIONS	
Dress Roll	Norton BPR 2203-20 (101 mm OD, 0.5 mm width)
Dress Speed Ratio	0.8
Dress Overlap Ratio	6
Dress Depth per Pass	0.013 mm
WORKPIECE MATERIAL	
Material	48-2-2 γ-Titanium Aluminide
Geometry	127 x 51 x 12.7 mm
Grinding Length	51 mm
OPERATIONAL CONDITIONS	
Wheel Speed	30 m/s
Material Removal Rates (MRR')	6.5 and 13.0 mm^3/s/mm
Depth of Cut	0.15 & 0.33 mm
Table Speed	42 mm/s

grinding process from an energetic standpoint, and is a commonly-used metric when characterizing grinding systems and applications. From Figure 5, SGE is observed to start low immediately after dress and increase steadily with each successive grinding pass. After approximately 1200 mm3 of stock removal, cracking was observed on the part and grinding under these conditions was stopped. The cumulative stock removed before the observation of part cracking is an important metric for testing purposes when comparing different abrasive products, as this value is an indicator of the relative dress interval required to avoid part damage when this failure mode is dominant. In addition to SGE and total stock removed before part damage, wheel wear and surface roughness were also measured. G-ratio was calculated to be approximately 6, while the average surface roughness (Ra) from damage-free grinds was 1.2 um.

Scanning Electron Microscopy (SEM) was used to characterize the wheel face of the conventional SiC wheel after testing. Images revealed localized adhesion of heavily deformed metal to cutting edges of the abrasive grits, as shown in Figure 6. This adhesion between grit and metal is known to increase frictional contributions to grinding power, and is likely the cause of the increase in power and specific grinding energy over time that was observed. Metal adhesion

3.2 Electroplated Diamond & cBN Wheels

Plots of specific grinding energy as a function of cumulative stock removed from testing of electroplated (EP) wheels containing diamond and cBN of both grit sizes tested are shown in Figure 7 and Figure 8. Data from the conventional SiC wheel previously discussed is also shown for comparison purposes. In the case of both grit sizes tested, the electroplated cBN wheel resulted in an increase in SGE during its use, although to a lesser degree than the conventional SiC wheel. Lower and more stable SGE progression was observed with the electroplated diamond wheels, regardless of diamond size. Part cracking was not observed after 18 passes (~1800 mm3) with any of the electroplated cBN or diamond wheels. Average surface roughness (Ra) from 60/80 mesh cBN and diamond wheels were 1.5 and 2.0 um, respectively, while 100/120 mesh abrasive resulted in average Ra values of 1.0 (cBN) and 1.6 um (diamond).

3.3 Dressable Metal-Bond Diamond & cBN Wheels

Dressable metal-bond wheels specifically designed to exhibit many of the beneficial characteristics of vitrified-bonded grinding wheels were also tested in the same manner as the conventional SiC and electroplated wheels. Both the dressable metal bond cBN and diamond wheels tested contained abrasive grits of 100/120 mesh size (average particle diameter of 151 um). Results of specific grinding energy progression can be seen in Figure 9. Again, wheels containing cBN abrasive displayed an increase in SGE over its use, while diamond abrasive resulted in low and stable SGE over time. Relative to the electroplated wheels which contain a single layer of highly exposed abrasive grits, the dressable metal bond wheels resulted in slightly higher grinding power and specific grinding energy primarily due to contributions from bond friction effects. Consequently, surface roughness with dressable metal bond wheels was lower relative to the electroplated equivalent, as average values for diamond and cBN wheels were measured to be 0.7 and 0.5 um, respectively.

SEM imaging of the wheel faces from dressable metal bond wheels revealed

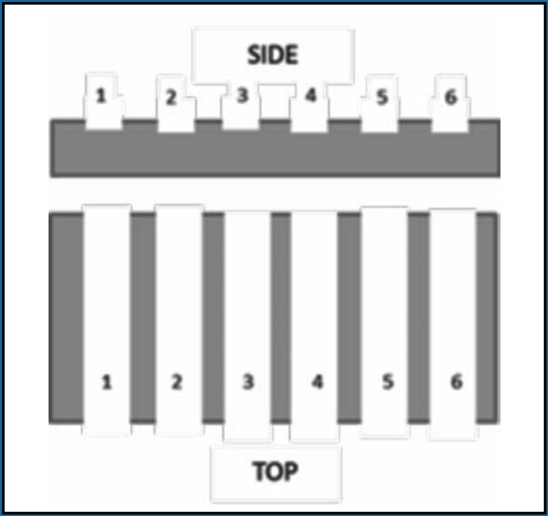


***Figure 3:* Workpiece Schematic**

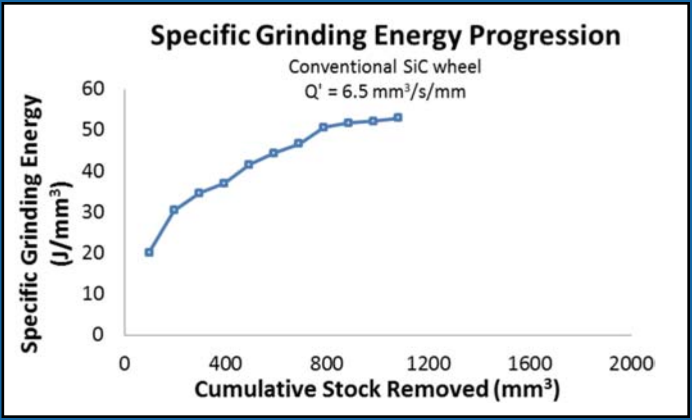


***Figure 5:* Specific Grinding Energy Progression for the Conventional SiC Wheel**

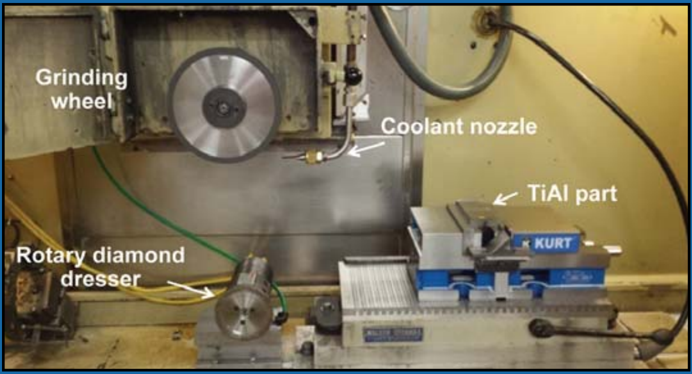


***Figure 4:* Photo of Machine Setup**

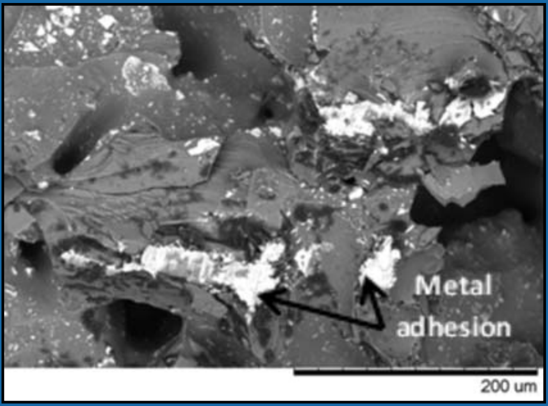


***Figure 6:* SEM Image of Used SiC Wheel Face, Showing Metal Adhesion on Active Grits**

some metal adhesion on the cutting edge of cBN grains, although this phenomenon was observed to be less prevalent when compared to the imaging results from the SiC wheel. Representative SEM images of a) cBN and b) diamond wheel faces are shown in Figure 10. The cutting edges within the diamond wheel were observed to be free of any metal adhesion. Based on the SEM images and grinding data from testing of various wheel types, the metal adhesion behavior appears to be driving the specific grinding energy increase over time, as the increased frictional effects from metal-on-metal sliding will consume more spindle power during grinding. Additionally, the lower average surface roughness associated with cBN wheels relative to diamond wheels is consistent with SGE progression and SEM results, as the additional rubbing and plowing of material associated with metal adhesion on cutting edges can reduce surface roughness.

3.4 Extended Duration Testing

Because workpiece damage was not observed during testing of grinding wheels containing cBN or diamond abrasive, additional testing on select wheels was performed at higher specific material removal rate (13 mm3/s/mm) and for a greater number of passes (up to 300) in attempts to induce material damage and to generate sufficient wear of the superabrasive wheels to enable G-ratio calculations. SGE progression for each wheel tested under these modified conditions, including the conventional SiC wheel, is shown in Figure 11. In can be seen that after increasing the total stock removed by orders of magnitude relative to initial testing, the difference between cBN and diamond is substantial, while the difference between cBN and SiC appears less significant. The conventional SiC and electroplated 100/120 grit cBN wheel removed 1200 and 3000 mm3 of material, respectfully, before part cracking was observed. In both cases, SGE was observed to increase over time. Both electroplated and dressable metal bond diamond wheels removed 140,000 mm3 of material without part damage (note: the x-axis on Figure 11 was truncated to show behavior of all wheels on same scale) and testing was stopped due all available material being consumed. While both diamond wheels display low and stable SGE over long periods of time, the dressable metal bond diamond wheel showed slightly higher SGE (< 10%) compared to the electroplated wheel. Again, this is attributed primarily to bond friction effects.

Table 3 shows a summary of several grinding process output metrics for all wheels subjected to extended duration testing at high material removal rate (13 mm^3/s/mm). Although these metrics can be used to aid grinding wheel selection, the most appropriate wheel technology for a specific γ-TiAl grinding operation will depend heavily on the requirements for part surface finish and geometric tolerances, as well as economic and machine tool considerations. For example, depending on dress frequency required and the target material removal rate, SiC-based wheels may be the most cost-effective solution. Alternatively, electroplated diamond wheels may provide the most benefit in roughing operations where low surface roughness is not required. Where overall grinding wheel life, form and finish tolerance, and process flexibility are critical, dressable metal-bond diamond wheels may be most advantageous. Ultimately, the best product solution is the one that delivers on the specific requirements of a particular end-user.

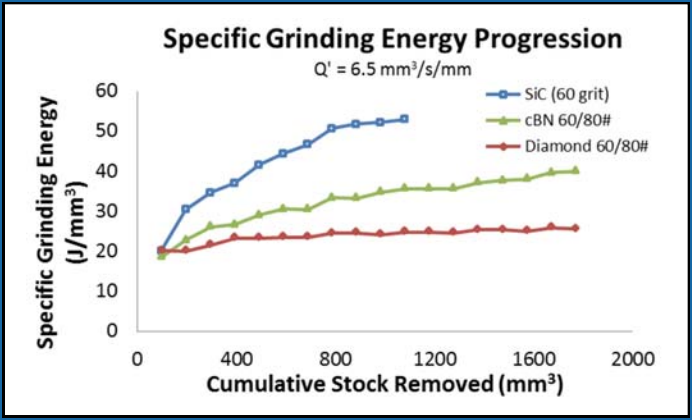


***Figure 7:* Specific Grinding Energy Progression for 60/80 Mesh EP Wheels**

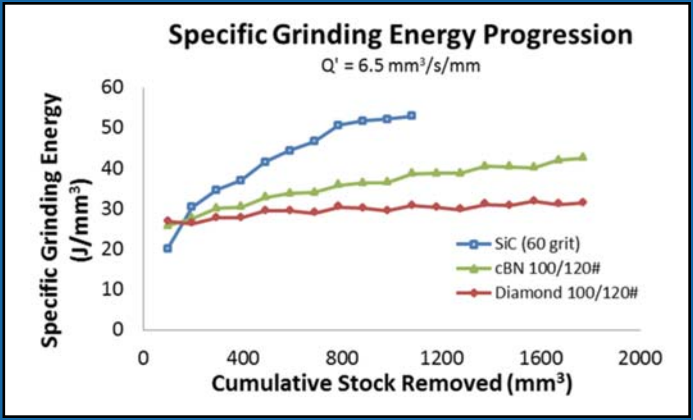


***Figure 9:* Specific Grinding Energy Progression for Dressable Metal Bond Wheels**

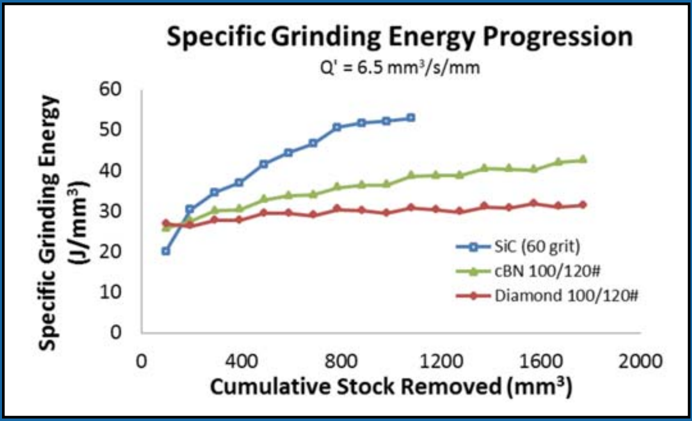
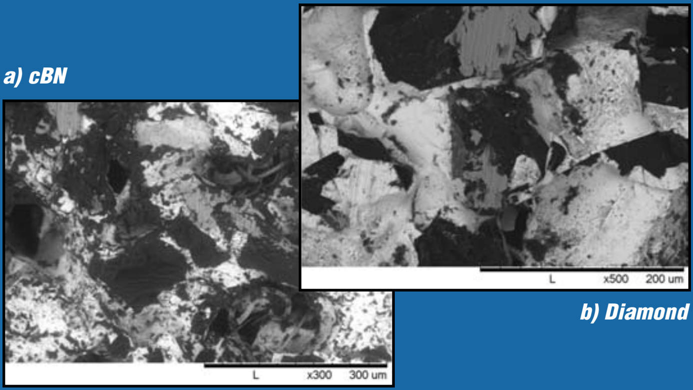


***Figure 8:* Specific Grinding Energy Progression for 100/120 Mesh EP Wheels**



a) cBN

b) Diamond

***Figure 10:* Representative SEM Images of Dressable Metal Bond Wheels**

3.5 Plunge Dress Demonstration

Plunge dressing is beneficial to many grinding operations due to improved cycle times and form tolerances that can be achieved relative to traverse dressing. Because the previous experiments utilized traverse dressing of metal-bond wheels, an experiment was performed utilizing plunge dressing and form grinding to more closely represent end-use of target applications.

A generic two-radii (r=6.25 mm) form of 0.55 mm depth was roughed into the dressable metal bond diamond wheel using a 150 mm (OD) dense metal-bond dress roll (IDW type). Final plunge dressing was performed using a dress speed ratio of +0.6 and an infeed rate of 0.127 um per wheel revolution. The wheel was then used to grind the full form into a new part, as shown in Figure 12, at 6.5 mm3/s/mm using grinding conditions listed in Table 1.

Results of specific power consumption as a function of grinding depth can be seen in Figure 13. Although the form depth on the wheel was 0.55 mm, successive slots were ground into the part until a total ground depth of 2.7 mm was achieved. The selected depth of cut value (150 um) resulted in the wheel becoming in complete contact (full form) with the part after the 4th grinding pass. A photograph of the formed slot mid-way through testing is shown in Figure 15, along with an optical comparator image of a graphite coupon, which captured the negative form of the wheel face cross-section after grinding. ●

***Table 3:* SUMMARY OF KEY OUTPUT METRICS**

WHEEL TYPE	Grit Size	Stock Removed	Avg. Ra (um)	G-Ratio
Vitrified-Bonded SiC (hardness L)	*60 grit*	*1200*	*1.2*	*5-10*
Electroplated cBN	*100/120*	*3000*	*1.0*	*60*
Electroplated Diamond	*100/120*	*>140,000*	*1.6*	*3000*
Dressable Metal-Bonded Diamond	*100/120*	*>140,000*	*0.7*	*600*

CONCLUSIONS

A systematic study of the effects of abrasive product type on the grinding of g-TiAl was conducted, which included conventional SiC wheels as well as electroplated and dressable superabrasive product types. Results indicate substantial technical benefits of diamond abrasive relative to cBN and SiC when grinding this material, although SiC-based wheel technology may still be appropriate depending on process and economic considerations. Effective damage free grinding was demonstrated with both electroplated and dressable metal bond diamond wheels at a specific material removal rate of 13 mm^3/s/mm with GRatio values of 3000 and 600, respectfully. Further, it was shown that dressable metal bond diamond wheels can be dressed in plunge mode and subsequently used for form grinding g-TiAl parts. This result suggests that such a process strategy could be employed to enable high-productivity grinding in operations where stringent dimensional tolerances and surface roughness requirements dictate the use of dressable abrasive wheels.

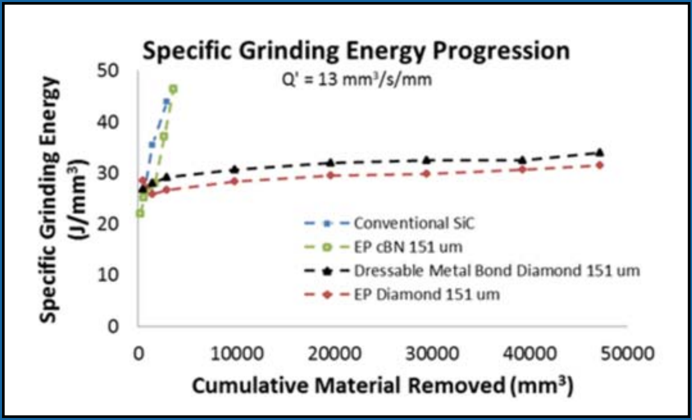


***Figure 11:* Specific Grinding Energy Progression for All Wheels Subjected to Extended Duration Testing**

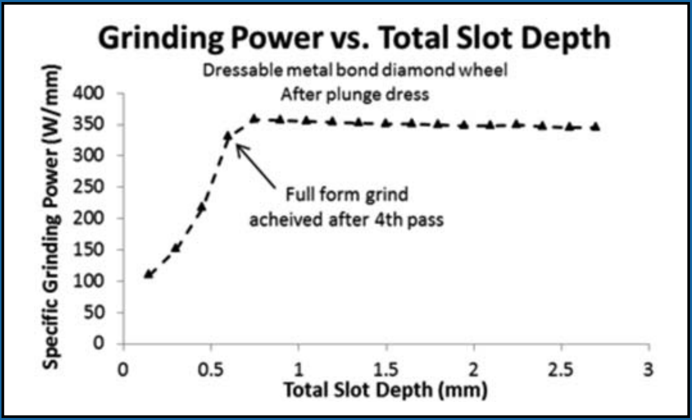


***Figure 13:* Grinding Power Progression During Form Grinding with Dressable Metal Bond Diamond Wheel (After Plunge Dressing)**

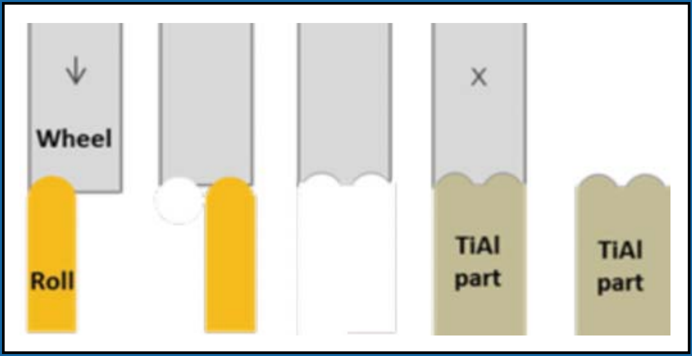


***Figure 12:* Schematic representation of plunge dress and form grind sequence, with motion direction indicated by arrow (downward motion) and x (motion in/out of page).**

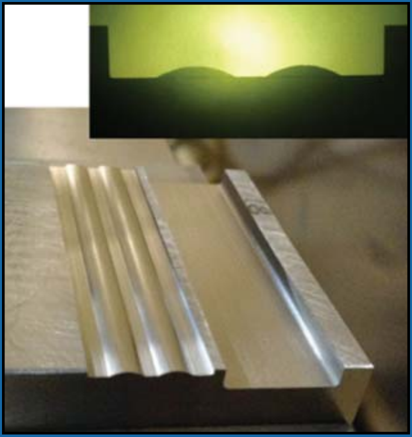


Figure 15:

Image of generic-form slot mid-way through testing and cross-section of the wheel face negative captured by graphite coupon.

FEDERAL-MOGUL ALLOY IMPROVES PISTON PERFORMANCE IN DIESEL ENGINES

August 17, 2015 – Federal-Mogul Powertrain has developed a new cast aluminum alloy one it claims will increase the strength of pistons for high-performance diesel engines, supporting higher mechanical loads that will result in higher specific power and greater efficiency. The DuraForm-G91 alloy would extend the performance life of diesel engine pistons by three to five times, compared to standard as-cast materials. The new composition increases fatigue strength in the hightemperature ranges typical for pistons of highly loaded diesel engines.

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September 15, 2015 – The CM-2600 motor is characterized by a very high torque-to-inertia ratio; it delivers rated torque of 0.189 Nm (26.8 oz-in) at a rated speed of 1125 rpm for a rated 22.3 watts of continuous power. The motor has a 19 mm (0.748 in.) inside diameter hollow stainless steel thru shaft (12.7 mm for the absolute encoder version). Peak torque is 0.69 Nm (97 oz-in) and no-load speed is 1900 rpm. CM-2600 series torque motors are specifically designed for direct-drive, high-resolution, high-speed positioning applications. Typical applications include optical instruments, multi-axis gimbal systems, scanners, and other direct-drive applications where use of a gearbox is undesirable for the commercial, industrial and aerospace and defense markets. ***For more information contact: www.Alliedmotion.com***

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Advanced Processes for the Precision Bore Finishing of Hydraulic and Automotive Components

By ROBERT MARVIN, Product Manager
Bore Finishing Systems – Engis Corporation

ABSTRACT

Reducing costs and improving quality have long been primary goals for most manufacturing operations. For the hydraulic and automotive industries these goals are currently being achieved with process advancements in precision bore finishing utilizing diamond tooling and customized machine tools. These advancements have made it possible to achieve bore size tolerances to within +/- 0.0013mm at high production rates and maintaining statistical process control. Improved bore cylindricity of under 0.001mm, and roundness as fine as 0.0001mm has also been achieved. This paper describes the various process techniques currently being used to achieve improved bore quality, faster production rates, customized surface finishes, and reduced overall costs per finished component.

Introduction

There are various processes and techniques that can be used for finishing the bores in components to high precision tolerances. These include Fine Boring, Precision Grinding, Reaming, Honing and Hand Lapping. Each process offers certain advantages over the others, as well as limitations. For example, Hand Lapping normally produces better bore geometry and surface finish than conventional Honing, but is much slower and more labor intensive. Precision Reaming can generally remove more material than conventional Honing, but cannot achieve as high of bore precision. This has led to the development of a hybrid process that combines aspects from each of the other processes to allow for higher production rates and overall bore precision. This process is Superabrasive Single-Pass Bore Finishing.

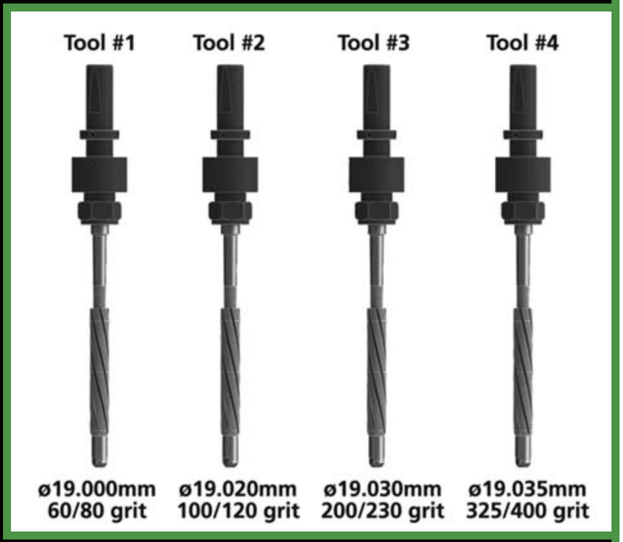
Superabrasive Single-Pass Bore Finishing was originally developed in the 1970's as a means for precision finishing through bores in Cast Iron Valve Bodies. Over the years the process has been refined to a point where almost any application, in a wide variety of materials can be finished in production. Ongoing research and development programs continue to find ways of slightly altering the process and the tooling to push the envelope of what can be achieved in regards to bore precision and productivity. achieved in regards to bore precision and productivity.

Process

The Single-Pass Bore Finishing process involves a series of pre-set superabrasive coated tools that get passed through a bore

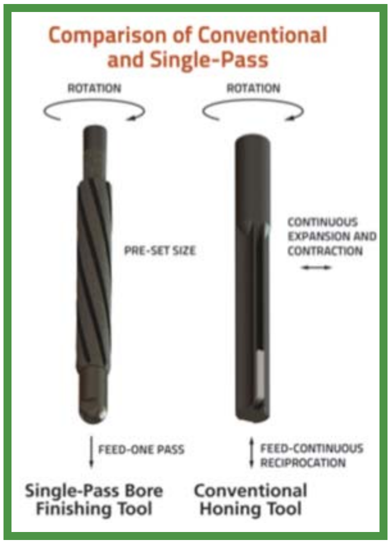
Superabrasive Single-Pass Bore Finishing System

> ***The Single-Pass process is in contrast to conventional honing where the tool or part is reciprocated many times while the abrasive portion of the tool is gradually expanded and retracted during each cycle.***



Typical Single-Pass Tool Progression

Once the Single-Pass tooling is properly broken in, size can be maintained for relatively long periods of time.


Comparison of Conventional and Single-Pass
ROTATION
ROTATION
PRE-SET SIZE
CONTINUOUS EXPANSION AND CONTRACTION
FEED-ONE PASS
FEED-CONTINUOUS RECIPROCATION
Single-Pass Bore Finishing Tool
Conventional Honing Tool

while the tool, part or both are rotating. In most cases each tool takes a “single-pass” in and out of the bore, but this can vary depending on the particular application and finish requirements. The total number of tools that are used in a set up will also vary depending upon the amount of stock to be removed, surface finish requirement, geometrical requirements and material make up. Generally each tool is set progressively larger in diameter, in ever reducing increments, while the grit size of the superabrasive is also reduced. This arrangement allows tools with larger superabrasive particles that remove relatively large amounts of material, and tools with smaller superabrasive particles that have finer surface finish capabilities, to be used progressively for maximum efficiency.

The Single-Pass process is in contrast to conventional honing where the tool or part is reciprocated many times while the abrasive portion of the tool is gradually expanded and retracted during each cycle. It is this pre-set characteristic, combined with the slow wear of the superabrasives, that allow the Single-Pass process to achieve the tightest bore size requirements with unmatched statistical process control.

Case History #1

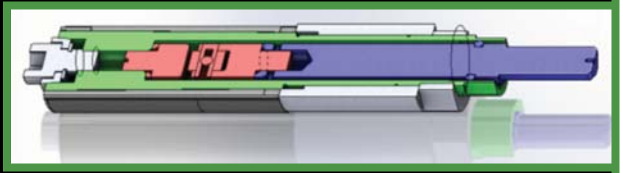
STEERING HOUSING		REQUIREMENTS	
Material:	Ductile Iron	Bore Tolerance:	+/-0.0013mm
Bore Size:	42.164mm	Roundness:	0.0013mm
Type:	Semi-Blind	Straightness:	0.0013mm
Length:	96mm	Surface Finish:	0.5Ra

Improved Size Control

Many hydraulic and automotive sub-assemblies require extremely tight clearances between mating components such as a spool and valve sleeve. Traditionally these types of components would be separated into classes for matching during assembly, or painstakingly matched during the finishing operations. The ideal method would, of course, be to make all of the components to an exact size and eliminate the need to match altogether, however, in most cases this has not been possible in production. The following case history illustrates how bore size tolerances to under +/-0.0013mm are now being achieved in production while maintaining statistical process control.

In order to achieve the best possible bore precision with the Single-Pass process it is very important that the cutting tools are allowed to follow the centerline of the existing bore with as little force as possible. This is accomplished by allowing either the component or the tooling to float. For applications where the part length is over three times the diameter of the bore, both axial and radial float should be applied. Due to the shape and weight of the Steering Housing in Case History #1, it was determined that it would be best to hold the part rigid and float the tooling; spring loaded holders were used to provide the radial float for the tool assemblies and a special free pivoting union was incorporated inside the mandrel of the tool for additional angle float.

Once the Single-Pass tooling is properly broken in, size can be maintained for relatively long periods of time. It is extremely



Tool Assembly Illustrating Internal Float Mechanism

Tool Mounted in an Automatic Size Adjustment Machine

important to not only monitor and control the size of the final finishing tool, but of each individual tool in the progression as well.

For this application a post-gage system was used to 100% inspect every finished part for size in the X and Y axis at the top, middle and bottom of the bore. A separate pre-gage system was incorporated to inspect each of the incoming parts and detect any undersize bore conditions prior to letting them index through the system. The pregage system would also automatically handle the periodic in-process size inspection for each of the semi-finishing stations. To do this the machine is designed to go into a "gage cycle" routine at prearranged intervals and index each of the parts on the table through the in-process gage. The gage would automatically tie in the size measurement of each part with its corresponding tool and list the sizes on the operator interface panel. If any of the sizes were found to be outside of the allowable process tolerance it would be flagged along with a message detailing the tool number and the exact amount of size adjustment that is required.

To adjust size the operator is required to remove the particular tool from the spindle by means of a quick change adaptor and place it into an automatic size adjusting machine. The data from the gage system then gets inputted into the automatic size adjusting machine and the calibrated adjustment is made. The operator would then verify that the tool setting height was correct and place the tool back into the spindle of the finishing machine.

For this application up to 0.038mm of Ductile Iron material needed to be removed. The bore had limited clearance at the bottom for the tool to pass through so a semi-blind bore finishing tool design needed to be incorporated. With this design the taper of the mandrel runs the opposite direction from standard tooling (larger diameter in the front of the tool) and the adjustment nuts are located behind the superabrasive sleeve. The tooling progression utilized a series of 6-tools ranging from 40/50 down to 200/230 mesh diamond.

Observations: In order to achieve the required bore precision each phase of the process had to be correct. This includes the Superabrasive Tooling, Part Holding Fixtures, Floating Mechanism, Machine Tool and Gage System. To be statistically capable for size the actual process tolerance needed to be held within a total range of 0.7um, including variation in bore shape and overall gage accuracy and repeatability.

Improved Surface Finish

In the past most surface finish requirements for precision bores were specified in Ra. Since Ra is an "arithmetic average" it is too general to describe the surface's functional nature. A surface with sharp spikes, deep pits or general isotropy may all yield the same roughness value. Ra makes no distinction between peaks and valleys, nor does it provide information about spatial structure.

Other common parameters such as Rz, Rt, and Rsk offer some improvements but still lack in the ability to properly quantify the desired profile. Because of this, a growing trend has been to turn to the Rk family of surface finish parameters.

The Rk parameters give a numerical summary of the information contained in the bearing ratio curve (Abbott- Firestone Curve), based on a division of the depth scale into three regions; Rpk (peak region), Rk (middle or core region), and Rvk (bottom or valley region). The following case history details the benefits of using the Rk family of parameters to quantify a surface finish in a bore and how to best achieve these requirements in production.

Anti-lock brake systems were developed for automobiles in the late 1960's. Their primary use was to avoid wheel lock up by rapidly pumping the breaks when engaged. Since the actual time that the system would be employed is very short, life cycles of

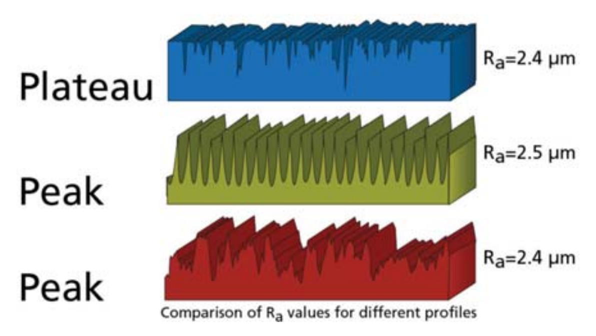
	DIAMETER	GRIT SIZE
Station #1:	42.130mm	40/50
Station #2:	42.147mm	40/50
Station #3:	42.157mm	40/50
Station #4:	42.161mm	60/80
Station #5:	42.163mm	100/120
Station #6:	42.164mm	200/230

Tooling Progression

BORE QUALITY	REQUIRED	ACHIEVED
Size:		
Roundness:	0.0013mm	0.0003mm
Straightness:	0.0013mm	0.0007mm
Surface Finish:	0.5Ra	0.25Ra

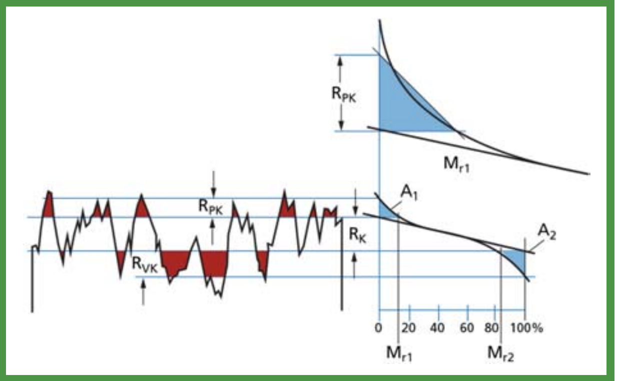
Application Results

Tooling Progression



Comparison of Ra Value with Different Profiles

> ***The Hydraulic Pump is the heart of an anti-lock braking system, providing the proper fluid pressure.***



Rk Family of Surface Finish Parameters

some of the components could be measured in minutes rather than hours. Advanced features on modern automobiles such as “Electronic Stability Control” and “Adaptive Cruise Control” have greatly increased the usage of these components and, in turn, require a much longer service life.

The Hydraulic Pump is the heart of an anti-lock braking system, providing the proper fluid pressure. The major components for this sub-assembly are the cylinder and the mating piston. To increase performance and overall life of the sub-assembly it was found that one of the major factors was the surface finish of the cylinder bore. As is the case with many similar applications, having too rough of a surface finish can cause excessive wear of the bore and mating piston during use. Conversely, if the finish is too smooth then proper lubrication between the mating parts may not be possible. To solve this complex problem the surface finish requirement of the cylinder bore had to be more clearly defined, specifying a certain depth of valleys to contain oil for lubrication, and a smooth, finer finish on the outer most material that could come into contact with the piston.

The above chart details the ideal surface finish parameters for the cylinder bore that would help achieve the desired performance of the sub-assembly.

It was quickly discovered that conventional bore honing processes would not be able to produce these results in mass

Case History #2

ABS PUMP CYLINDER		REQUIREMENTS	
Material:	Hardened Steel	Bore Tolerance:	+/-0.004mm
Bore Size:	8.000mm	Roundness:	0.002mm
Type:	Blind Bore	Cylindricty:	0.005mm
Length:	16mm	Surface Finish:	Special

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SURFACE FINISH	
Parameter	Requirement
Rpk:	< 0.15
Rk:	> 0.40
Rvk:	> 0.30

production with any acceptable statistical capability. The manufacturer ultimately settled on an Engis Bore Finishing System customized specifically for the application and particular surface finish requirements.

The customized system utilized a machine tool with six spindles and a rotary table that could use the Single-Pass process for maximum productivity. The part holding fixtures were on a gimbal base that would allow for angular float. Since the bore of the cylinder had limited clearance at the bottom, blind bore style tools had to be used. This style tool also required self-centering floating tool holders for radial positioning.

One of the advantages of using a multi-tool process is that each tool can be set to achieve a certain parameter within the surface finish requirement. For this particular application it was broken up into four distinct stages.

The first stage is to use a 100/120 grit diamond tool to remove the majority of the incoming material and achieve a very specific size and maximum surface finish. By doing so it can be assured that the deepest scratches would not damage the final results.

The second stage is to use a 200/230 grit diamond tool to produce a finish that will establish the valleys in the final surface texture.

The third stage uses a 325/400 grit diamond tool that is set to only remove the peaks of the finish produced in stage #2.

The fourth stage uses a very fine diamond brush that does not measurably change the bore size but does remove microscopic torn and folded debris from the surface.

Observations: With the specially designed system the parts were able to be consistently finished to the required surface finish at high production rates. Each machine automatically finished 240 parts per hour and with an overall perishable tool cost of under $0.03 per finished part.

Improved Productivity

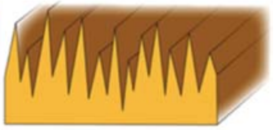
When developing a large volume production process for precision finishing bores, the Single-Pass process is almost always the best choice due to total cycle time and overall tooling costs per piece. Depending on the particular application, there are various ways to tailor the process to further increase the overall productivity. Some of these ways include:

- Stacking of parts
- Additional spindles and stations on a dial or transfer machine with multi-indexing
- Automation system tending multiple machines at a time
- Utilizing additional spindles and spreading the total stock over more tools
- Special multi-head designs for simultaneously finishing a series of bores in part The following case history illustrates how one manufacturer was able to utilize some of the latest advancements of the process to increase production by more than 300%

The Valve Body in Case History #3 had three inline

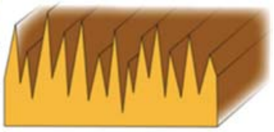
Special Designed Tooling Specifically for Application

Stage #1	
Size:	-0.004/-0.006mm
Finish:	< 3.5Rz



First Stage Uses a 100/120 Grit Diamond Tool

Stage #2	
Size:	-0.001mm
Finish:	1.75 to 2.50 Rz



Second Stage Uses a 200/300 Grit Diamond Tool

Stage #3	
Size:	Final Size
Finish:	< 0.15Rpk

Third Stage Uses a 325/400 Grit Diamond Tool

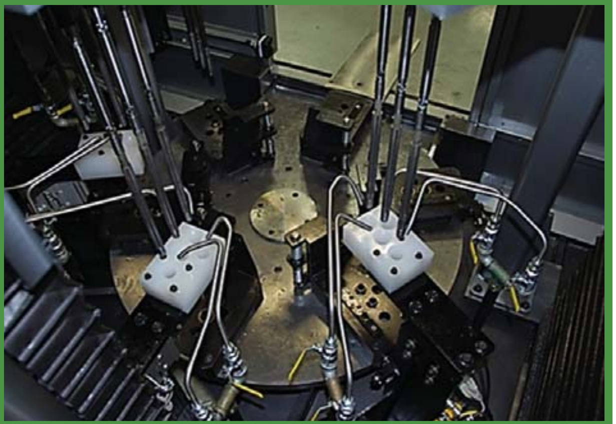
Stage #4	
Parameter:	Final Size
Rpk:	< 0.15
Rk:	> 0.40
Rvk:	> 0.30

Fourth Stage Uses a Very Fine Diamond Brush

Case History #3

MONOBLOCK VALVE BODY		REQUIREMENTS	
Material:	G2 Casting	Bore Tolerance:	+/-0.002mm
Bore Size:	15.877mm	Roundness:	0.002mm
Type:	Through Bore	Cylindricty:	0.005mm
Length:	200mm	Surface Finish:	0.5Ra

Engis Single-Pass Bore Finishing System



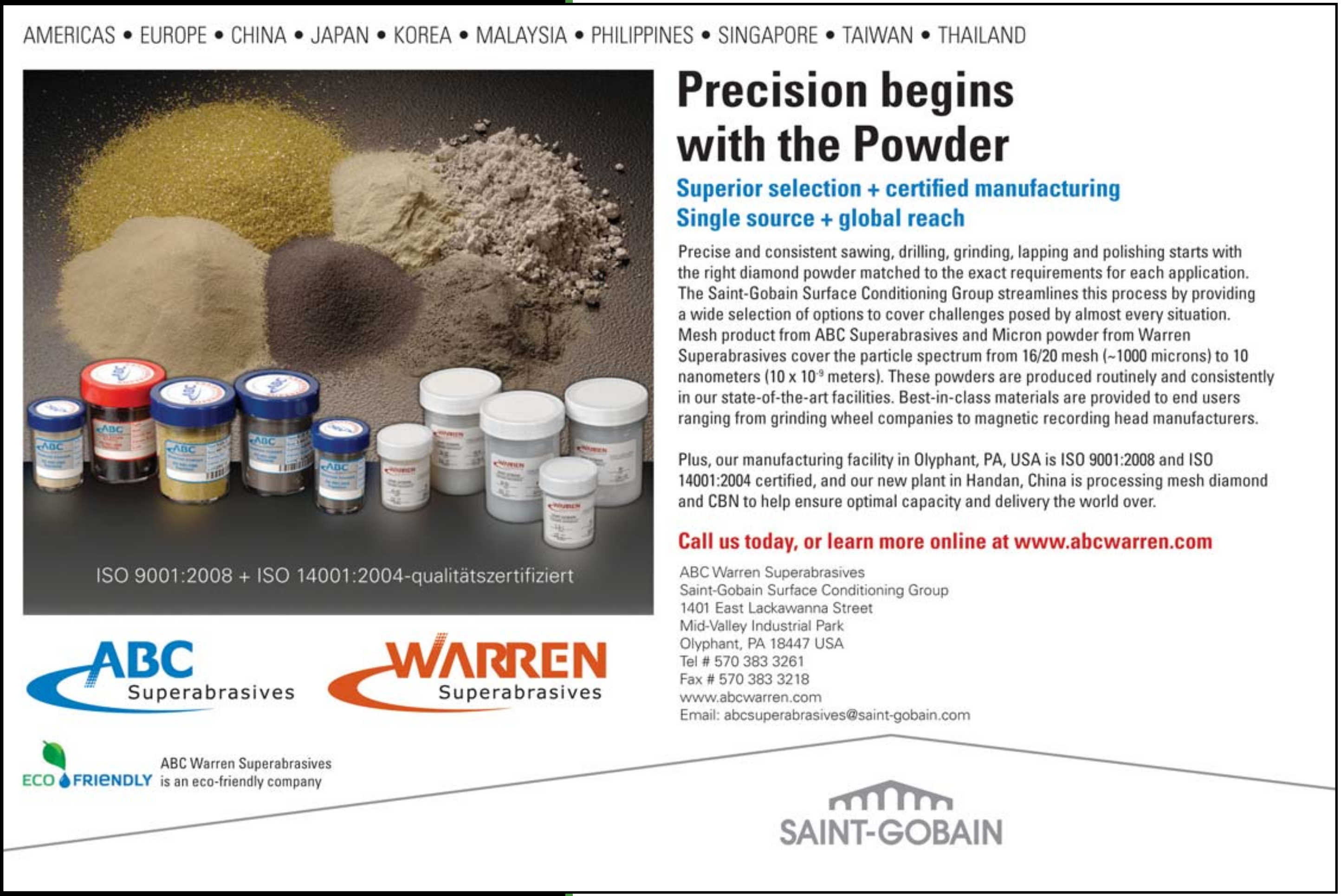
Machine Layout with Special Multi-Head Design for Finishing 3 and 4 Bore Parts

15.877mm diameter spool bores that needed precision finishing. To achieve the desired tolerances the manufacturer was originally using a 3-tool Single-Pass process on a special dial machine. This machine was designed so that the rough, semi-finish and finish operations could all performed simultaneously on separate parts around the dial, but only on one bore in a part at a time. The parts would then need to be manually repositioned and run through the machine three times until all of the bores were finished.

In 2012 the manufacturer developed a new model that included a fourth 15.877mm diameter spool bore adjacent to the other three. It was apparent that the existing machine would not be able to accommodate this additional requirement so the manufacturer looked for alternatives. The solution that was decided upon was a specially designed Engis Single-Pass Bore Finishing System that included a series of custom multi-heads that could simultaneously finish all four bores in the valve body.

The machine was designed with six stations located around a rotary index table for maximum productivity.

- Station #1 is the load/unload position
- In Station #2, a vision system is used to verify that the part is loaded correctly and that the proper part is present for the current program being run.
- Stations #3, #4 and #5, each have independent servo controlled columns, with four spindle multi-heads for holding the diamond honing tools.
- Station #6 utilizes an independent servo controlled column with a head holding four multi-jet gage probes. This gage unit allows every land of every bore to be inspected in the X and Y planes for size. The gage also has advanced features which allow it to measure the bore sizes of the rough and semi-finish operations on command.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To remove the 0.06mm of G2 material a three stage tool progression was used: 100/120 grit diamond for the rough pass, 200/230 grit diamond for the semi-finish and 325/400 grit diamond for the finish pass. The diamond length of the tool was designed 200mm long so that any camber in the bore could be removed and produce total bore cylindricity to under 2 microns.

Observations: With this unique design the manufacturer was able to increase productivity by 300% to 400%. The improved diamond tooling allowed the process to achieve a higher bore precision capability, and just as important, the special features of the system keep the process running as efficiently as possible. As an additional bonus, the perishable tooling on average lasts over six months in the machine without needing to be changed, further increasing productivity and reducing the overall cost per piece. ●

	DIAMETER	GRIT SIZE
Station #1:	15.862mm	100/120
Station #2:	15.872mm	200/230
Station #3:	15.877mm	325/400

Tool Sequence

BORE QUALITY	REQUIRED	ACHIEVED
Size:	+/-0.005mm	0.002mm
Roundness:	0.002mm	0.0005mm
Cylindricity:	0.005mm	0.002mm
Surface Finish:	0.5Ra	0.25Ra

Application Results

CONCLUSION

Continued development of the Superabrasive Single-Pass process has led to many breakthroughs that are now being employed throughout the Automotive and Hydraulic industries. Bore size, geometrical shape, and customized surface finishes are now being held to higher precision levels than previously thought possible in mass production. In fact, bore size control has now surpassed what can be achieved with the outside diameter finishing of the mating components and has reached the limits of current air gage capability.

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